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USSR Space Life Sciences Digest

Issue 18

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NASA Contractor Report 3922(21)

USSR Space Life Sciences Digest

Issue 18

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* Topics marked with * have no entries of their own, but refer readers to relevant abstracts included in other topic areas.

USSR Space Life Sciences Digest: Issue 17 Reader Feedback Form

To our readers: We are working in a large number of highly technical, specialized areas for which adequate Russian-English glossaries have yet to be compiled. We ask your help in improving the accuracy and specificity of our English terminology. Please fill out the form below whenever you encounter an incomprehensible, incongruous, awkward or otherwise inappropriate term. While we solicit all suggestions for improved renderings, the statement that a term is inappropriate provides us with useful information, even when no better alternative can be suggested. A copy of this form will appear in all future issues of the Digest. Thank you for your help.

Abstract #	Incorrect or contextually inappropriate word or phrase:	Suggested rendering: ("??" is an acceptable entry)
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FROM THE EDITORS

This is Issue 18 of the USSR Space Life Sciences Digest. This issue includes the 1000th abstract completed since the Digest's inception in 1985. The following abstracts contain or discuss space flight data: Adaptation P822, P857; Body Fluids P836; Cytology P823; Endocrinology P834, P835; Genetics P850; Immunology P849; Musculoskeletal System M126; Psychology M130; Special Feature P856. Abstracts P857 (Adaptation) and P856 (Special Feature), a book chapter and letter to the editor respectively, appeared to be of particular interest and were translated in their entirety. Readers requesting new subscriptions, address changes, or subscription cancellation should be aware that the requested changes will almost certainly not be put into effect with the next issue to be published, but with the one after that. Delays are due to the need to include mailing labels with manuscripts submitted for printing.

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ADAPTATION

(See also: Metabolism P829, P831; Psychology P818, M130;
Special Feature P856)

PAPERS:

P822(18/88) Komolova GS, Yegorov IA.

Biosynthesis of nucleic acids in the lymphocytes of rat spleen during chronic exposure to extreme conditions.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 276.

Hematology, Lymphocytes; Metabolism, Nucleic Acids, Synthesis, Spleen
Rats, Reproductive Biology, Pregnancy, Developmental Biology
Adaptation, Hypoxia, Hypokinesia, Space Flight Factors, COSMOS-1514

Abstract: Evaluation of the nature and extent of an animal's adaptation to extreme environmental conditions is a critical issue in space biology. The present work establishes that during phenotypical adaptation, metabolism of nucleic acids in the lymphocytes of an animal's spleen is a sensitive quantitative and qualitative indicator of the progress of adaptation in the body.

The authors studied the rate of synthesis of DNA and RNA in rat lymphocytes in response to chronic exposure to a variety of factors (hypoxia, hypokinesia, space flight factors). Synthesis of nucleic acid was measured by inclusion of in situ labelled radioactive precursors. In rats moved from sea level to high altitudes (3200 - 3400 m) or exposed to equivalent conditions in a barochamber, biosynthesis of nucleic acids in spleen lymphocytes was shown to depend directly on stage of adaptation. Depression of DNA and RNA biosynthesis during the acute period of adaptation was followed by substantial activation (by approximately a factor of 2-4) during the hyperfunction stage of physiological adaptation. In long-term adaptation, these parameters normalize, although heterogeneity of nuclear precursors of messenger RNA is altered. In long-term hypokinesia, the synthesis of nucleic acids in spleen lymphocytes decreases and is correlated with changes in parameters of skeletal muscles. After space flights lasting up to 22 days, biosynthesis of nucleic acids decreases, as it does after long-term hypokinesia. However, in pregnant rats flown on the COSMOS-1514 biosatellite, RNA synthesis was stimulated in spite of depression of replication (by approximately 42%). There is reason to believe that such stimulation is functionally associated with increased nucleic metabolism throughout the mother's body, evidently serving to support flexible homeostasis in the fetus.

Based on the data obtained, the authors propose that parameters of nucleic acid synthesis in spleen lymphocytes be used to assess adaptation to chronic extreme conditions in animals.

P824(18/88) Farber YuV.

The effects of the adaptation process on tolerance of extreme factors.

In: Gizenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 324.

Radiobiology, Human Performance

Rats

Adaptation, Tolerance, Nonspecific, Extreme Factors, Hypoxia, High Altitude

Abstract: The variety of environmental conditions in which people must work imparts practical significance to research on the ways adaptive reactions affect tolerance of extreme conditions. We are gaining increasing understanding of the role of adaptation to a particular environment in decreasing the effects of a number of physical agents, including ionizing radiation.

This paper considers experimental data on changes in radiosensitivity and altitude tolerance during adaptation to moderate chronic hypoxia at high altitudes. In the relevant literature, acclimation to high altitude is treated as synonymous with adaptation to hypoxia, and is considered to be accompanied by increased tolerance to a set of additional environmental factors. Such changes in tolerance are traditionally termed nonspecific. It is assumed that nonspecific adaptive reactions are strategic in nature. When evaluating the effects of high altitude on tolerance of other extreme factors, it should be remembered that resistance to acute hypoxia is the specific, and resistance to radiation is the nonspecific component of the adaptive reaction.

Research was performed on white outbred rats at 3200 m above sea level. Radiation resistance was determined by noting subjects' survival rate on day 30 after irradiation with a dose of 9 Gy (dose rate 0.5 Gy/hr), beginning on days 3 - 80 of adaptation with intervals of 2-4 days. Rats' tolerance of acute hypoxia was evaluated by noting the mean duration of survival at an altitude of 12,000 m (in a barochamber), and by counting the increased number of resistant individuals surviving after a 10-minute exposure to radiation at a given altitude. The research was conducted on animals either irradiated at a dose of 8.0 Gy or not irradiated, and either adapted to high altitude or not adapted. It was established that: 1) tolerance for specific (hypoxia) and nonspecific (ionizing radiation) factors increased, and 2) there was a positive correlation between tolerance of hypoxia and radiation resistance. Study of radiation resistance of rats adapting to high altitude conditions at 3200 m above sea level for 80 days showed that by day 25 of exposure to high altitude, tolerance had increased by a factor of 1.5 relative to a control group. Subsequently, there were fluctuations in mean level of resistance to radiation, with the maximum level being 3 times that of the control. The protective effect of preliminary exposure to high altitude hypoxia was demonstrated by an increased number of animals surviving, and by the lethal dose increasing by 100-150 rads in prolonged irradiation at a dose rate of 0.5 Gy/hr. These changes in radiation

ADAPTATION

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sensitivity were, at least partially, due to decreased radiation damage to the hemopoietic system, as reflected in an increased pool of hemopoietic stem cells, increased regeneration in hemopoietic tissue, and increased production of hemopoietic cells. In irradiated, nonadapted rats, tolerance to acute hypoxia decreased during the most severe period of radiation sickness. As radiation damage healed, specific tolerance to hypoxia increased in this group of animals and on day 20 after irradiation (day 23 of adaptation), tolerance reached that of the nonirradiated (control) group. Tolerance of acute hypoxia did not change significantly in irradiated adapted animals and was equivalent to that of the control group.

Thus, adaptive reactions which occur in response to specific environmental conditions may be correlated with increased tolerance of other extreme factors. As duration of adaptation increases, sensitivity to stress factors decreases.

P857(18/88)* Gazonko OG, Grigor'yev AI, Yegorov AD.

Taxonomy and time course of adaptive responses in humans on long-term space flights.

In: Furduey FI, Kaydarliu SKh, Shrirby YeI, Nadvodnyuk AI, Mamalyga IM.

Mekhanizmy razvitiya stressa: Stress, adaptsiya i funktsional'nyye narusheniya [**Mechanisms underlying the development of stress: Stress, Adaptation and Functional Disorders.**]

See M130 (Psychology) in this Digest Issue.

[30 references; 13 in English]

Authors' Affiliation: Institute of Biomedical Problems, USSR Ministry of Health

Adaptation, Time Course, Cardiovascular and Respiratory Systems,
Endocrinology, Hematology, Immunology, Metabolism, Microbiology,
Musculoskeletal System, Neurophysiology
Humans, Cosmonauts
Space Flight, Long-term, Salyut-6, -7, Soyuz, Soyuz-2

Translation: All space flight factors are not equally important from the standpoint of inducing changes in physiological functions. The insignificant dosage of ionizing radiation, the Earth-like cabin atmosphere, as well as the larger size of modern space stations precluding hypokinesia attenuate the effects of these factors. The effects of hypodynamia inherent in space flight are partially compensated by physical exercise and performance of job tasks. Nervous and emotional stress, inducing reactions at various levels of neural and humoral integration, have significant physiological effects on cosmonauts only at the most critical stages of the flight (insertion into orbit, docking, EVA, landing, etc.). Thus, weightlessness would seem to be the most important space flight factor inducing physiological shifts and this is confirmed by ground-based simulation studies. The direct effects of weightlessness are associated with elimination of gravity deformation and mechanical stress on body structures, leading to decreased functional loading on a number of physiological systems. Indirect effects of weightlessness are associated with working and living conditions in space, which, coupled with decreased activity in postural tonic musculature, induce changes in coordination and locomotion, which in turn affect job performance and daily activity.

Theoretical analysis allows us to postulate that afferent impulses from mechanoreceptors decrease in weightlessness. This may result from stress in the hollow smooth muscle organs (those with contents) and deformation of their tissues and parenchymes; stress on the ligaments which hold the visceral organs in place; stress on the postural-tonic musculature and the new muscle efforts required to move in the absence of gravity; and unloading of the bone and cartilage systems.

Evidently, the mechanism underlying changes in afferent impulses from the vestibular system in weightlessness is extremely complex. The hypothesis of functional deafferentiation of the labyrinth does not accord with experimental data indicating that only stimulation tangential to the macula causes effects (Trinker, 1962). This implies that since the utricle lies in the horizontal plane, impulses generated by any head position in space will be equivalent to those for the head held upright in normal gravity.

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Ye. M. Yuganov's (1963, 1968) hypothesis that short-term weightlessness is a kind of minus-stimulus for otolith receptors is consistent with the idea from general physiology that abrupt cessation of stimulation initially leads to increased impulses from the receptor system, due to effects on the first derivative. However, because of the short duration of this effect (less than a minute), the minus-stimulus cannot be considered a cause of space motion sickness on long-term flights.

The decrease in neural impulses from mechanoreceptors in weightlessness may be accompanied by decreased activity in the dorsal portion of the hypothalamus and reticular formation, as well as attenuation of its ascending and descending effects. Consequences would include decreased inhibitory effects from afferent impulses along the ascending tract, improved transmission of afferent impulses along the conductive tracts, and altered regulation of the receptor system and change in the number of its active units. These mechanisms might well maintain the required level of excitation in the central nervous system in microgravity.

It is possible that decreased activity in the dorsal portion of the hypothalamus lowers the activity of the hypothalamus-pituitary-adrenal system, which, in turn, leads to decreased secretion of ACTH, corticosteroids, and catecholamines. This is confirmed by results of space flight research.

Nervous-emotional stress, which may be experienced at various stages of space flight, has a stimulating effect on the higher central nervous and hypothalamus-pituitary-adrenal systems. The ultimate reaction to the simultaneous effects of weightlessness and emotional stress depends both on the duration of exposure to these factors and on the individual's personality.

The state of weightlessness is characterized by redistribution of body fluids, with a relative increase in their volume in the upper portion of the body. This redistribution is linked to the absence of hydrostatic pressure in body fluids, particularly blood, during weightlessness. This, state produces a condition, which requires amendment of Starling's hypothesis that interstitial fluid reenters the capillaries increasing the volume of blood plasma. The headward shift in blood and interstitial fluid induces increased venous return, increased central cardiac volume, distension of the vessels in the cardiopulmonary area and a number of reflex reactions in this area. All of these effects lead to changes in parameters of the cardiovascular system and fluid-electrolyte metabolism.

Headward displacement of blood evidently persists for a long period of time. This is demonstrated by data obtained by Thornton, et al. (1977) demonstrating a persistent headward shift in the center of gravity in humans throughout an 84-day flight.

Decreased loading of the muscle system and decreased muscular tonus may, on one hand, lead to decreased energy expenditure and stress on the oxidative processes, and, on the other hand, to a diminished role of the musculature in hemodynamics.

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Changes in the major human physiological functions in weightlessness. At the present time, there have been 13 long-term space station flights (1 month and longer). Of these, 10 (1 to 7 months in duration) were conducted by the USSR with 17 cosmonauts (4 of whom flew twice), while the US has had 3 flights (1 to 3 months in duration) with 9 astronauts (3 per flight).

The following taxonomy of symptoms developing on long-term space flights is based on the results of medical studies performed on these flights.

Initial phase of the flight (first week)

- Space motion sickness
- Acute fluid shift to the upper body
- Development of a new motor program

Long-term exposure to space flight conditions

- Change in motor afferent system and muscles
- Change in fluid electrolyte metabolism and its regulation
- Change in the level of cardiovascular functioning accompanied by orthostatic and physical deconditioning
- Change in calcium metabolism and bone tissue mineralization
- Change in function of adrenal glands and associated endocrine organs
- Development of functional anemia
- Decreased immunological reactivity

Space motion sickness is observed, at some level of severity, in 30-40% of individuals exposed to space and arises during the first 3-6 days of a flight. At present, we are still not able to reliably predict the severity of space motion sickness symptoms. Some cosmonauts have also developed symptoms during the first few days after reentry.

At present there are several hypotheses concerning space motion sickness (See Table 1).

The most likely hypothesis postulates that weightlessness disrupts the organization and coordination of the sensory systems responsible for spatial orientation. This theory is based on Reason's (1969) formulation describing how sensory conflicts develop. The hypothesis that otolith asymmetry plays an important role in the development of space motion sickness in flight and after reentry is also based on the sensory conflict theory. (Yegorov, BB, Samarin GI, 1970; Van Baumgarten, Thumler, 1979).

Hemodynamic redistribution (blood shifts to the upper body) that impedes normal outflow from the brain may lead to increases in intracranial pressure and stimulation of the vestibular nuclei (Bryanov II, Matsnev I.EI, Yakovlev IYa 1975). Resulting changes in hormonal status may also play some role in development of space motion sickness (Kohl et al, 1983).

The characteristics of the functional systems of statokinetics and spatial orientation (Anokhin PK, 1971) may also be very important in space motion sickness etiology. It may be postulated that these systems transmit afferent impulses to the central nervous system that characterize the unfamiliar external and internal environment in weightlessness and for which

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Table 1: Mechanisms underlying occurrence of space motion sickness

1. Disruption of interactions among afferent systems and the development of sensory conflicts**On Earth**

Spatial orientation is based on afferent impulses from the vestibular system, visual organs, proprio- and enteroreceptors, etc. Information from these systems is complementary and corresponds to past experience stored in memory (neural model).

In Weightlessness

Information from various vestibular receptors and other sensory systems is inconsistent and contradicts the neural model developed on the basis of previous experience. This leads to the development of sensory conflicts, of which the most important are vestibulo-visual and canal-otolith conflicts.

2. Otolith Asymmetry**On Earth**

The CNS handles innate differences in the weight of the right and left otolith membranes by compensating for the deficit in stimulation from the lighter membrane.

In Weightlessness

Asymmetry is caused by continued CNS compensation for the differences in otolith weight. This gives rise to motion sickness until a new compensatory mechanism is developed. Persistence of this mechanism again causes asymmetry upon return to 1-g.

3. Hemodynamic shifts

In weightlessness, the redistribution of body fluids in the cranial direction induces changes in intracranial pressure, which affect the excitability of vestibular nuclei and are conducive to motion sickness.

4. Changes in endocrine functions

In weightlessness, the concentration of ACTH in blood plasma decreases, while the concentration of hydrocortisone increases. Data from ground-based studies indicate that this situation may increase susceptibility to motion sickness.

memory holds no corresponding model laid down by phylo- or ontogenetic experience. The uniqueness of the situation signalled by these impulses and the absence of a corresponding model in memory hampers the formation of an appropriate motor program and selective blockade of inappropriate functional neural connections. All this may lead to inadequate adaptation, and thus, to further attempts at optimization. The body, evidently, needs a certain amount of time to acquire experience and to find and select the optimum reactions. (See Table 2)

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Table 2: Formation of a functional system of statokinetics and spatial orientation on Earth and in weightlessness (hypothesis)

ON EARTH	IN WEIGHTLESSNESS
Causal Factors	
Effects of gravity and change in body position while performing job tasks, locomotion, assumption of various postures, etc.	Change in body position while performing job tasks, locomotion, assumption of various postures in the absence of gravity.
Stages of afferent synthesis	
Comparison, selection, and synthesis in CNS of many afferent streams from the external and internal environments providing information on statokinetics and body position in space (dominant motivation, information about the environmental situation, memory).	Occurrence of sensory conflicts and change in the nature of afferent stimulation, leading to stimulation reflecting unfamiliar external and internal environment, for which memory contains no precedent from phylo- or ontogenetic experience.
Stages of decision making	
Blockade of the many functional neural connections in the central sensory system that are not relevant to attaining the current goal (permitting adequate statokinetics and spatial orientation). Formation of a motor program and a mechanism for evaluating its results (acceptor).	Difficulty in forming a motor program ("uniqueness" of the situation as signalled by absence of a memory model corresponding to the afferent inputs) and in selectively blocking goal-irrelevant neural connections.
Stages of efferent synthesis	
Inclusion of locomotor autonomic components in response to efferent commands, and programmed movements leading to assumption of a particular posture, performance of the necessary locomotor movements or formation of correct spatial orientation.	In this "unique" situation the individual may have to make one or several choices of motor program and the one selected may yield adequate or inadequate results.
Results of the movement (feedback)	
The parameters of the result obtained (statokinetics and orientation) are transmitted to the acceptor in the CNS and are compared to the prediction. When there is a mismatch the structure of the functional system changes and ultimately leads to the desired result	Given an inadequate result, the individual needs some time to acquire individual experience, for search and selection of a more optimal means to obtain the desired result

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Redistribution of blood to the upper body occurs on the first day of flight. After a relatively short time (approximately a week), its subjective symptoms gradually diminish (but do not always completely disappear). These symptoms include: sensation of blood rushing to the head, stuffy nose, smoothing of facial wrinkles, facial puffiness, increased blood perfusion and pressure in the veins of the neck and in parameters of blood perfusion in the head. Calf volume decreases and the tissue higher than the heart shows slight edema.

Changes in motor function in flight are characterized by the development of new motor programs during the first few days of flight. Initially, the time required to perform certain tasks increases and calibration of the muscle force appropriate to a particular movement is hindered. However, after several days of flight these movements regain the necessary accuracy, the effort necessary to perform them decreases, and motor efficiency increases.

After long-term exposure to weightlessness other symptom clusters develop. These are described below.

Postflight changes in the kinesthetic system and muscles (Kozlovskaya, et al., 1981) include: atonia of the posterior group of calf muscles; subatrophy or sometimes atrophy of a number of antigravity muscles; decrease in the strength parameters of the calf muscles; altered sensory inputs to this system (decreased threshold of vibration sensitivity in the support zones of the feet and tendon T-reflex of the gastrocnemius muscle), and changes in interlimb coordination and changes in motor regulation (disruption of locomotor function and regulation of vertical posture). Extent of the changes observed is not a direct function of flight duration. Such changes may be associated with altered receptor sensitivity and muscle deconditioning as a result of "disuse" or "inadequate use" resulting from decreased loading.

Changes in fluid electrolyte metabolism and its regulation in flight include: overall loss of fluid (first week of flight); increased renal excretion of potassium, sodium, and aldosterone; and a tendency for excretion of ADH to increase. At the same time, the concentration of angiotensin in blood plasma is elevated (Leach, Rambaut, 1977).

A detailed study of fluid-electrolyte metabolism and renal function after 75-185 day flights in the Salyut-6 -- Soyuz program revealed fluid retention, decreased extracellular fluid volume, decreased renal excretion of sodium, and increased excretion of calcium and potassium. The concentration of potassium in plasma decreased, while the concentration of the ionized fraction of calcium increased. Study of the osmotic and ion-regulating functions of the kidneys after fluid-electrolyte loading revealed an imbalance in the ion-regulation system with opposite effects on excretion of fluid and of certain ions. Changes in hormonal regulation after long-term flights included increased renal excretion of aldosterone and ADH.

Changes in potassium metabolism included increased excretion of this ion and negative potassium balance during and after short- and long-term

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flights (Leach, Rambaut, 1977; Gazenko OG, Grigor'yev AI, Natochin YuV, 1980; Burnazyan AI, Gazenko OG, 1983). Total concentration of metabolizable potassium in the body also decreased postflight (Leach, Johnson, Alexander, 1975). Increased renal excretion of potassium was observed after all long-term flights in spontaneous diuresis, as well as in potassium chloride, calcium lactate, and fluid loading tests. Negative potassium balance may be associated with atrophic processes in the muscles, increased protein catabolism, and loss of cell mass in weightlessness, leading to loss of potassium from the cells and renal excretion of the excess. In other words, loss of this ion is not associated with nutritional deficit, but with reduced storage of potassium in the body.

Changes in fluid-electrolyte metabolism evidently reflect a process of adaptation to headward fluid shifts. The body responds to the associated distension of the central veins and auricle as if it were an increase in circulatory volume, causing partial loss of fluid and electrolytes by triggering the mechanisms inhibiting secretion of antidiuretic hormone and possibly other hormones. Researchers (Fisher et al., 1967; Johnson et al., 1977; Burnazyan AI, Gazenko OG, 1983) have noted decreases in circulating blood volume, plasma, and interstitial fluid, which may be considered the result of such reactions.

Adaptive changes in the renin-angiotensin-aldosterone system play an important role in supporting fluid-electrolyte homeostasis during the postflight period. These changes lead to increased renal excretion of aldosterone, and also decreased concentration of renin and aldosterone in the blood. Such changes have occurred in the majority of cosmonauts and astronauts returning from long-term flights.

Changes in calcium metabolism lead to decreased bone mineralization, increases in calcium and phosphorus in plasma and renal excretion of these ions both during and postflight (Leach, Rambaut, 1977; Whedon, et al, 1977; Rambaut, Johnson, 1979; Gazenko OG, Yegorov AD, 1980; Vorob'yev YeI, et al., 1984).

Increases in blood concentration of parathyroid hormone and renal excretion of hydroxyproline and nitrogen have been noted during flight. Increased calcium excretion reflects changes in the state of bone tissue in weightlessness, which may be related to decreased skeletal loading, decreased deformation forces, changes in blood vessels and flow, and alteration of bone metabolism.

Decreased loading/stress on the skeletal system is undoubtedly accompanied by diminished neural impulses from osteoreceptors, which, in conjunction with decreased activity of the hypothalamus-pituitary system, may lead to decreased secretion of thyrocalcitonin and thyroxin (Leach, Rambaut, 1977). This entire set of changes may be accompanied by resorption of bone tissue, mobilization of calcium from storage, decreased osteoblast function, and diminished bone formation and calcification. However, at present, this hypothesis concerning bone demineralization has not received direct experimental confirmation.

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Changes in functioning of the adrenal glands and associated endocrine organs during flight are manifested in: decreased plasma ACTH and a tendency for hydrocortisone to increase; nonsignificant fluctuations in renal excretion of adrenalin and noradrenalin; decreased or unchanged renal excretion of total 17-hydroxycorticosteroids, and simultaneous increase in excretion of hydrocortisone and total 17-ketosteroids.

The following changes in hormonal regulation were observed after long-term flights in the Salyut-6--Soyuz program (Tigranyan RA, et al, 1983): activation of the sympathetic adrenal system (with predominance of the hormonal link during the first few days, and of the mediator link thereafter) and glucocorticoid function of the adrenal glands in the absence of changes in plasma ACTH, TSH, and STH; some increase in concentration of cGMP; less increase in cAMP; a reliable decrease in prostaglandin activity; and simultaneous activation of the kallikrein system.

The hypothesized decrease in activity of the posterior lobe of the hypothalamus in weightlessness probably causes decreased plasma ACTH. The decrease in plasma ACTH, decrease or unchanged renal excretion of 17-OCS and catecholamines noted during space flights attest to the absence of a pronounced stress syndrome under normal conditions of orbital flight. This is confirmed by experiments performed by Soviet and Czechoslovak scientists on rats which had spent 20 days on board the COSMOS-782, -936, and -1129 biosatellites. It was demonstrated that the concentration of noradrenalin and the activity of catecholamine-containing enzymes in the hypothalamus of rats sacrificed immediately or 26 days after reentry were no different than those in control animals and ground-based synchronous groups. At the same time, the concentration of catecholamines in certain individual nuclei of the hypothalamus decreased. These data also indicate that weightlessness does not act as a long-term stressogenic stimulus. Analysis and comparison of the results of studies performed in- and postflight support the conclusion that onset of weightlessness and exposure for 7 months induce less stress on physiological systems than subsequent readaptation to normal gravity. Thus, the set of stimuli characteristic of normal gravity may be considered a kind of stressor for humans acclimated to space.

Changes in cardiovascular functions on long-term space flights include: signs of increased cardiac contraction strength (primarily during the first month of flight); in a number of cosmonauts, short-term (during the first 10 days of flight) increase in cardiac stroke volume and a tendency to long-term slight increase in minute circulatory volume; tendency to slight decrease in blood pressure parameters (with the exception of end systolic pressure); decreased venous pressure gradient (this parameter increases in the jugular vein and decreases in the area of the calf); increased compliance of the venous reservoir of the calf and simultaneous decrease in contractility; increased plethysmographic pulsed blood perfusion parameter in the vessels of the head with pronounced decrease in tonus of arterioles and small veins in this area, and decrease in pulsed perfusion of the vessels of the calf.

Data from provocative tests administered inflight demonstrated, in a number of cases, the development of signs of orthostatic and, less often, physical deconditioning. However, more severe decreases in physical work capacity and

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orthostatic tolerance were observed postflight.

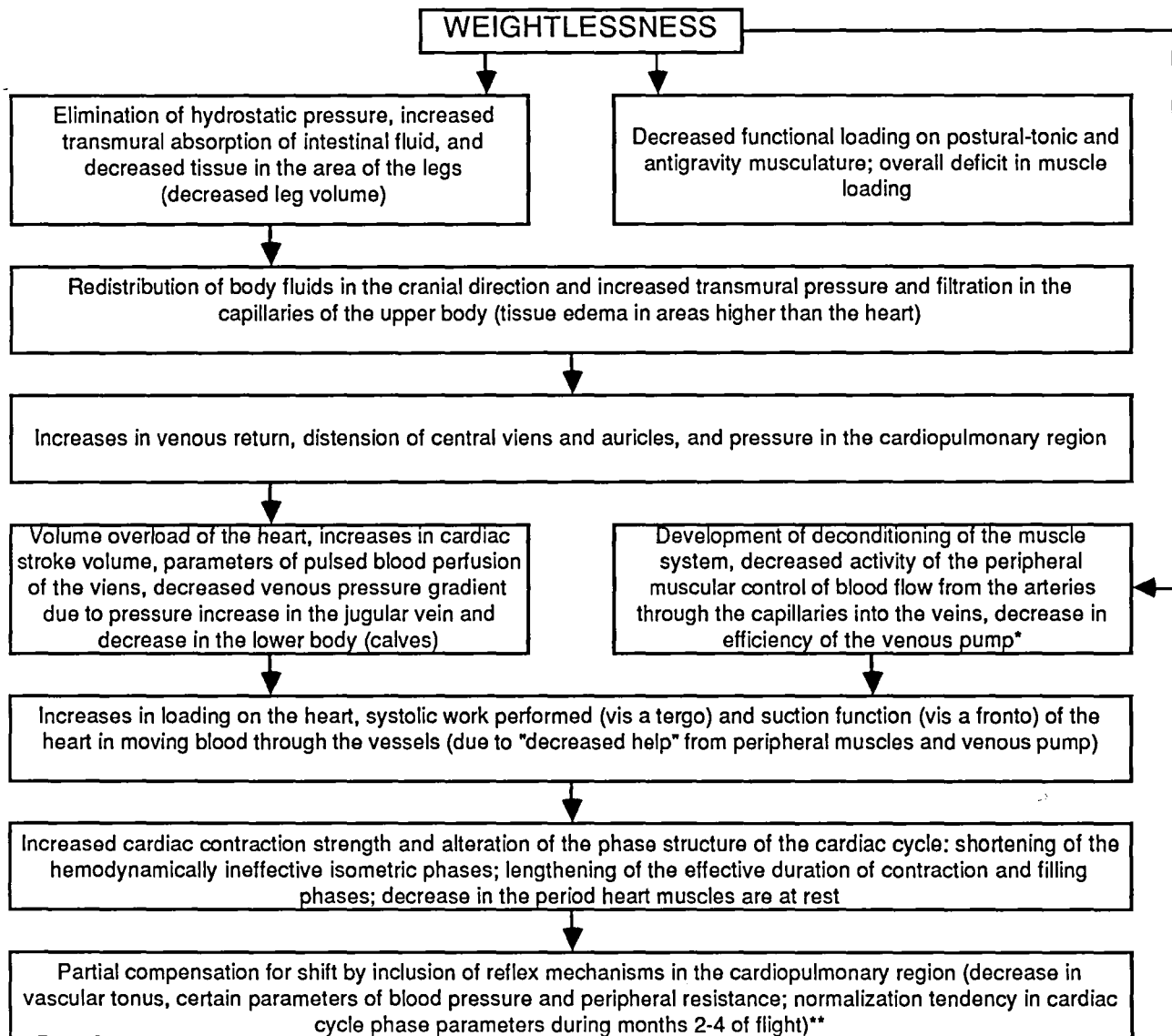
The process of formation of adaptive reactions and shift to a new functional level of cardiovascular activity and general circulation clearly occurred during the first month of flight, as shown by follow-up observations. Subsequently, circulatory parameters at rest and during provocative tests were relatively stable.

Changes in the cardiovascular system observed during long-term space flights are probably caused by the redistribution of blood and interstitial fluids in the cranial direction, leading to an increase in venous return and cardiac "volume overload." As a result, cardiac ejection and blood perfusion and pressure in the jugular veins tend to increase, while pressure in the veins of the calf decreases.

Decreases in postural-tonic activity and stress on the antigravity musculature, and also the constant deficit of muscle activity during long flights, diminish the significance of peripheral muscular control of blood flow (Arinchin NI, Nedvetskaya GD, 1974) and muscle pumps and heighten the role of systolic work performed by the central heart and its suction function (active diastole) in circulation. All this may facilitate an increase in stress on the heart, which manifests itself in restructuring of the phase structure of the cardiac cycle: shortened isometric contraction and relaxation phases, and lengthened (primarily, during the first month of flight) ejection period and rapid filling phase. (See Figure 1.)

The increase in blood perfusion of the cranial areas of the body, undoubtedly, triggers reflex mechanisms by receptors of the vessels in the cardiopulmonary regions, resulting from the distension caused by increased blood volume. The reaction occurring here, according to research by V.V. Parin, F.Z. Meyerson (1965), V.N. Chernigovskiy (1960), R.D. Marshall, J.T. Shepherd (1972), and Shepherd (1974), serves to decrease the volume of circulatory blood and limit its flow in the cardiopulmonary region.

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* - data obtained during space flights;

** - tendency for pressure in veins of various regions to be maintained at the level of venous or right arterial pressure

Figure 1: Possible mechanisms underlying changes in the cardiovascular system in weightlessness

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Ultimately, blood flow to the heart is balanced, the circulatory system attains a new functional state with a different blood pressure : blood volume ratio, and the shifts occurring in weightlessness are partially offset (normalization of stroke volume, normalization tendency in phase structure of the cardiac cycle, decreased blood pressure and peripheral resistance):

Development of compensatory reactions of the cardiovascular system in weightlessness

Reflex reactions triggered by receptors in vessels in the cardiopulmonary region (resulting from their distension by increased blood volume) include:

inhibition of the vasomotor center, increased tonus of vagus and triggering of unloading reflexes as a result of impulses from receptors in the pulmonary vessels (Parin VV, 1946) limiting the flow of blood to the heart and reducing tonus of the vessels in systemic circulation (in flight there is a tendency for blood pressure and peripheral resistance to decrease);

excretion of a portion of fluid through the Henry-Gauer response and decrease of central blood volume as a result of increasing blood pooling when receptors of the auricles and pulmonary vessels are stimulated (Parin VV, 1946; Chenigovskiy VN, 1960);

partial compensation for the extent of the shifts (normalization of stroke volume beginning in months 2-3 of flight -- normalization of the long ejection period and tendency for other cardiac cycle parameters to normalize) and stabilization at a new functional level for circulation due to triggering of compensatory mechanisms from the carotid sinus (Marshall RD, Shepherd, JT, 1968).

It may be hypothesized that carotid sinus reflex mechanisms play an important role in stabilizing the circulatory system at a new level in long-term flight. These mechanisms remain in force throughout the entire period spent in space and dominate effects of other cardiovascular mechanoreceptors (Marshall RD, Shepherd JT, 1972). At the same time, it should be remembered that long-term exposure to space (weeks or months) is evidently accompanied by changes in neurohumoral reactions. In particular, the amplitude of reactions triggered by baroreceptors and adrenergic reactions (Nicogossian, Parker, 1982) may decrease. Ultimately, there is an overall decrease in tolerance for gravity.

Anemia occurring after long-term flights manifests itself in decreases in plasma volume, erythrocyte and hemoglobin mass, number of erythrocytes in peripheral blood, and in decreased erythrocyte size and proportion of discocytes, and in some cases increases in the number of echinocytes, spherical and dome-shaped forms, erythrocytes with low weight and fractions with high electrical charges (Johnson, Driskol, Leblanc, 1977; Kimzey, 1977; Balakhovskiy IS, Legen'kov VI, Kiselev RK, 1981; Nicogossian, Parker, 1982; Burnavayan AI, Gazenko OG, 1983). Number of erythrocytes and concentration of hemoglobin in a unit volume of blood and growth of reticulocytosis were most pronounced during weeks 2-3 of flight. Level of erythrocytes in blood

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plasma and urine increased severalfold on days 7-10 of flight.

The shifts observed in the immediate postflight period attest to some degree of hypohydremia, decreased plasma volume and circulatory blood, which undoubtedly results from reflexive adaptive reactions developing during flight in response to increased circulatory blood volume in the cardiopulmonary region. It can be assumed that the loss of fluid and decrease in plasma volume occurring in flight and leading to an increase in the hematocrit, as well as a relative increase in erythrocyte weight, combines with decreased physical activity to inhibit erythropoiesis. In addition, decreased activity of the posterior lobe of the hypothalamus in response to weightlessness may play some role (Figure 2).

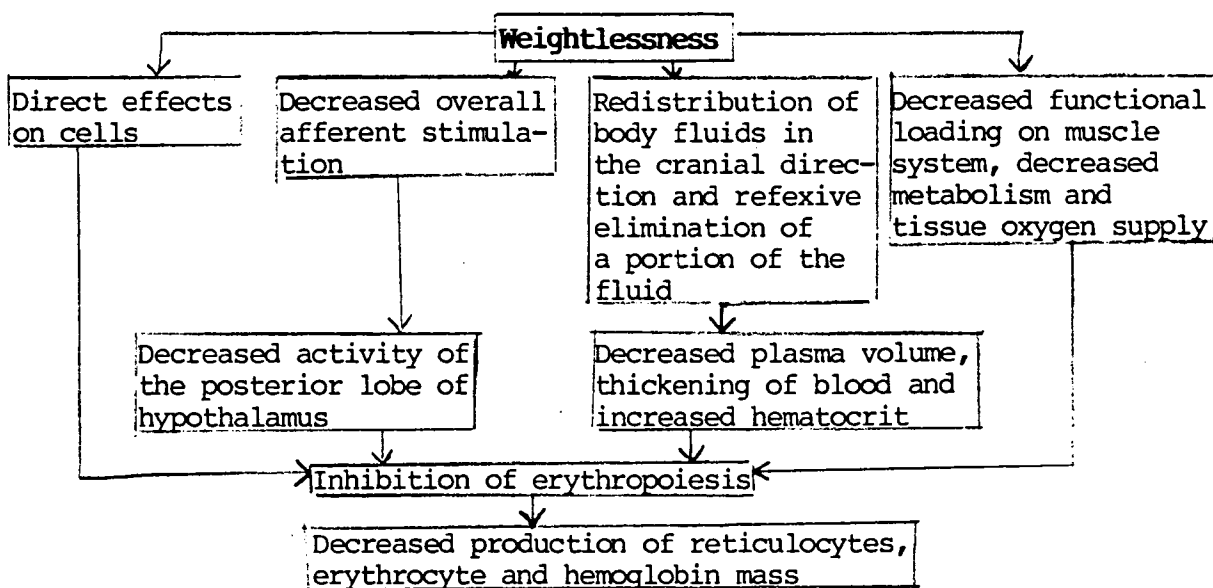


Figure 2: Hypothetical model of the mechanisms underlying changes in the erythropoietic function in weightlessness

In the postflight period, initially blood plasma is restored relatively rapidly, leading to a still greater decrease in concentration of erythrocytes and hemoglobin in a unit volume of blood. Subsequently, there is a slow recovery of total erythrocyte mass accompanied by an increase in the number of reticulocytes and the level of erythropoietin. The quantitative and qualitative recovery of red blood parameters was complete approximately 1.4-2 months after long-term flights in the Salyut-7-Soyuz-T and Salyut-6 - Soyuz programs.

Changes in immunological reactivity (Konstaninova IV, et al.) after space flights include decreased concentration and activity of T-lymphocytes in blood and also decreased T-helpers and natural killers, while suppressor activity remained unchanged.

Changes in automicroflora on long-term space flights (Zaloguyev SN, et al.) are characterized by: some increase in microbial concentration on skin and

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mucous membranes; dysbacteriotic shifts in automicroflora of the integuments, mucous membranes and intestine; increased resistance of microflora to antibiotics; signs of pathogenicity in some microorganisms.

Thus, changes in immunological reactivity are polymorphic. Their magnitude was not found to be a direct function of flight duration and was evidently determined by individual features of the organism, prophylactic measures taken (pre- and inflight), and (possibly) phase changes.

As the above implies, one of the major conclusions from medical research performed on long-term flight programs is the demonstration that it is possible, in principle, for humans to perform goal-directed, productive work in weightlessness up to 7 months in duration. The changes observed in various physiological systems in- and postflight were adaptive in nature, appropriate to the factors engendering them, affected neither work capacity nor fulfillment of the flight mission, and were reversible. The extent of the shifts occurring in response to space flight was not a direct function of their duration and was probably determined, to some degree, by the number and regimens of prophylactic measures employed.

The changes described and the mechanisms underlying their development in space flight are a function of time and reflect the process of physiological adaptation to weightlessness, which supports self-regulation, and serves to maintain homeostasis of vital parameters. In agreement with the concepts of P.K. Anokhin, self-regulation mechanisms are triggered when vital parameters deviate from a constant level and act to restore this level. The final adaptive effect may be attained more readily if, in addition to self-regulation of internal linkages within the functional system, external factors are also included, in particular, prophylactic countermeasures. On the basis of the principles of self-regulation, we have developed a model of the time parameters of the process of adaptation of humans to weightlessness. This model includes a number of periods and phases. We have identified a period of adaptation, including a phase of initial adaptive reactions, a major adaptation phase, a phase during which adaptive reactions are completed, and also a period of relative stabilization of adaptive reactions.

The phase of initial adaptive reactions (duration up to a day) is characterized by deviation from a constant level and occurrence of initial reactions to weightlessness (fluid shifts, change in afferent impulses from mechanoreceptors, disruption of functional organization of sensory systems, and elimination of loading on the musculoskeletal system). Typical of this phase are spatial disorientation, sensation of blood rushing to the head, and, in a number of instances, symptoms of motion sickness, disruption of motor coordination, and other changes.

Major adaptation phase (duration approximately 1 week) is marked by initial restructuring of physiological functions and their regulatory systems with triggering of compensatory-adaptive reactions. Previously occurring reactions, including the sensation of blood rushing to the head and heaviness of the head, edema of soft tissues higher than the heart, and motion sickness symptoms continue in this phase. Objective examination reveals increase in systolic volume and cardiac ejection, increased venous

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pressure and pulsed blood perfusion of the vessels of the head, change in phase structure of the cardiac cycle, and a number of other changes.

Restructuring of the functions of regulatory systems, evidently, involve changes in cortical-subcortical relationships and decreased activity of the hypothalamus-pituitary system. The increased excretion of potassium and sodium noted during this period probably leads to some loss of fluid and electrolytes, decrease in plasma volume and total volume of circulatory blood, and of red blood cell mass and body weight. Decreased loading on the musculoskeletal system acts as a trigger, evoking changes in bone tissue metabolism with increased calcium loss.

As these shifts occur, evidently, adaptive mechanisms are triggered that prevent further progression and to some degree attenuate these shifts. The hypothesized decrease or elimination of the deficit in central nervous system stimulation in weightlessness is produced by changes in self-regulation mechanisms and cyclic interactions of cortical and subcortical structures. Work demands, cosmonauts' level of motivation, and the increased informational input to the visual and auditory systems play important roles in this process.

Vestibular and motor disturbances are compensated for by development of a new functional organization of the sensory systems and new motor programs.

Increased central blood volume, leading to distension in the cardiopulmonary region, triggers reflex mechanisms which counteract the changes in the cardiovascular system and fluid-electrolyte metabolism occurring as a result of fluid redistribution in the cranial direction.

Phase of completion of major adaptive reactions (duration, 4-6 weeks) is marked by further development of adaptive reactions and restoration (partial or complete) of the final adaptive effects of a number of physiological functions.

Period of relative stabilization of adaptive reactions is manifested in the establishment of a new level of functioning of the major physiological systems and completion of development of homeostasis, which, in the absence of additional extreme effects, may be retained for a long period of time.

The problem of the duration of individual phases and periods of adaptation has not yet been resolved and requires further research.

AVIATION MEDICINE
(See also: Psychology M131)

PAPER:

P832(18/88)* Strongin GL, Skvortzov SA.

Individual differences and individual norms revealed in automated preflight medical monitoring.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 10-16; 1987.

(4 references; none in English)

Aviation Medicine, Operational Medicine, Preflight Exams; Equipment and Instrumentation, Automated Monitoring Devices; Human Performance
Humans, Pilots
Individual Differences

Abstract: This paper describes the methodology and results of automated preflight examination techniques and emphasizes the need to derive individual norms in preflight medical monitoring. The automated system for preflight medical monitoring included the following elements: 1) an apparatus for automated gathering, processing, evaluating, and storing psychophysical information; 2) software for maintaining archives of preflight examination data, deriving and monitoring individual norms, preparing reports on examinations, and scientific processing of data; 3) communication lines between the examination site, the computer center, and flight physicians. The equipment at the examination point allows the following parameters to be recorded: 1) complaints; 2) heart rate; 3) systolic blood pressure (in the finger); 4) diastolic blood pressure (in the finger); 5) body temperature; 6) level and polarity of the ST segment in the first standard electrocardiographic lead; 7) amplitude and polarity of the T wave in the first standard lead; 8) cardiac arrhythmia; 9) time and error parameters in a visual motor selection task; 10) percent of uncorrected deviation in tracking tests; 11) number of correct answers in a test of working memory. All psychophysiological tasks and parameters were recorded by computer. Each series of tests took 4 minutes. Information was printed along with confidence intervals for group and individual norms. When a parameter fell outside the normal range an "alarm signal" was printed. The system was tested at a number of airports with number of test points ranging from 10,000 to 242, depending on parameter. The following statistics were computed for each parameter: group statistics: mean, standard error of the mean, standard deviation, number of observations; individual statistics: maximum value, minimum value, range, mean, standard error of the mean, median, 25th and 75th percentiles, mode, standard deviation, variance, coefficient of asymmetry, standard error of asymmetry, coefficient of excess, and standard error of excess. It was determined that normative values had to reflect normal status of flight crews preflight, rather than resting values. For example, mean heart rate was 10 strokes/min faster during preflight testing than for subjects at rest. The authors argue that group norms are not sufficiently sensitive to changes in an individual's functional state and that norms derived from an individual's previous parameter values should be used instead.

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Table 1: Statistical characteristics of parameters recorded with automated preflight monitoring

Table 2: Boundaries of norms for individual statistic characteristics

Table 3: Magnitude and signs of correlation in 20 subjects

Figure 1: Flow diagram of conduct of automated preflight monitoring

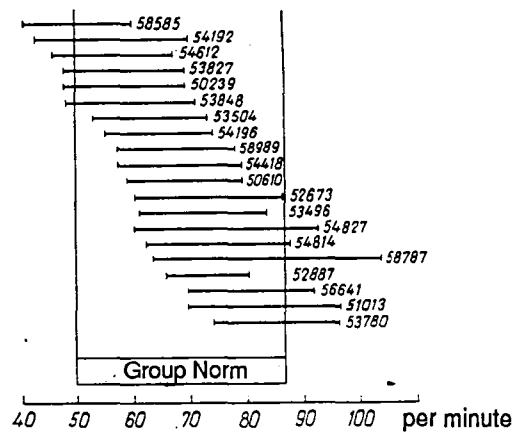


Figure 2: Relationship between group and individual norms for heart rate in 20 subjects.

BOOK REVIEW:

BRL3(18/88)* Peshkov YeM.

Review of: Rudnyy NM, Vasil'yeva PV, Gozylova SA (editors). Aviatsiyonnaya meditsina: Rukovodstvo [**Aviation medicine: A Handbook**] Moscow: Meditsina; 1986. 579 pages, 6000 copies.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina. 22(2): 95-97; 1988.

KEY WORDS: Aviation Medicine, Human Performance, Personnel Selection, Habitability and Environment Effects, Man-Machine Systems, Nutrition, Operational Medicine, Pharmacological Countermeasures, Perception

Abstract: In 1986, the "Meditsina" publishing house published the handbook "Aviation Medicine." For their material, the authors have relied on achievements in such disciplines as physiology, psychophysiology, engineering psychology, ergonomics, pathological physiology, aviation hygiene, toxicology, industrial physiology, radiobiology, pharmacology, aviation biochemistry and others. The handbook covers a broad range of issues relevant to support and optimization of crew performance during flights on aircraft of various types, organization of work and rest schedules, maintenance of crew health, and means and methods for combatting fatigue. The characteristics and methods of occupational selection, medical support of flight safety, flight certification exams, and prevention of disease are discussed as well. Specific measures for medical support of long-term flights and flights at low and high altitudes are also presented.

The handbook describes the major environmental factors affecting humans on aircraft flights: barometric pressure, gaseous composition of the atmosphere and inspired air, acceleration, noise, vibration, ionizing radiation, superhigh frequency electric fields, toxic substances, and microclimate factors. It considers the mechanisms through which these factors operate and ways to protect humans from their adverse effects.

When flight factors reach certain levels (in magnitude and duration) they may have adverse effects on human work capacity as well as on human health. For this reason, flight physicians must pay particular attention to the ways these factors affect flight personnel.

Continual improvement of existing aviation technology and development of new technology, increasing levels of power, velocity, distances, altitudes, and load and passenger capacity of aircraft have increased the emphasis placed by aviation medicine on man-machine interactions and human factors. For this reason, the handbook provides an in-depth examination of these issues, particularly the effects of altitude factors on the functional state of the body and performance of complex operator tasks. It describes techniques for increasing tolerance of oxygen deficit and protection against decompression sickness that may develop at altitudes greater than 7000 m on flights in nonpressurized cabins.

Issues covered include emergency egress from aircraft by parachute, physiological effects of acceleration, noise, vibration, toxic substances from fuels and lubricants. The extensive use of polymer materials in construction of new aircraft has necessitated more studies directed at

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preventing deleterious toxic effects in flight and engineering-maintenance personnel.

Flights into extreme climatological zones require studies on the effects of various temperatures on flight personnel. Also covered in this handbook is the development of appropriate clothing and prophylactic means of heating or cooling.

The book presents new approaches to the physiological and hygienic considerations relevant to daily nutrition of flight crews on long flights and under emergency conditions. The authors discuss these issues scientifically, taking into account the practical interests of the flight physician. The handbook describes in detail the psychophysiological workload of aviation specialists.

In the early days of aviation the attempts of physicians to study inflight performance of pilots were tentative. There were neither appropriate methods for performing research, nor adequate criteria for estimating the work capacity of pilots during flight. As appropriate methodologies were developed or borrowed from other sciences (physiology, psychology, and hygiene) and put into extensive use, aviation physicians were able to increase the objectivity with which they evaluated and standardized flight tasks.

A number of recent works have concentrated on describing conditions and characteristics of work on various types of aircraft. With the increased complexity of cabin equipment and instrumentation, and the appearance of new automated systems of control, complex displays and warning indicators, speech simulators, video screens depicting conditions in the air and on the ground, and other devices, the attitudes of flight physicians, engineers and pilots to inflight working conditions on new aircraft have undergone significant changes.

It has become essential to consider a number of important circumstances, including the increased complexity of flight missions and interaction with ground control systems and the mounting difficulty of performing an increasing number of operations at a faster rate. The need for accurate performance and the responsibility of crewmembers for completing flight missions have increased. It has become essential to seek new approaches that comprehensively examine the set of psychophysiological and hygienic components of the ergatic pilot-aircraft-environment system. It is important to study the emotional, mental, and physical components of flight performance, and the psychomotor, proprioceptive, cognitive, and autonomic characteristics of pilots.

At present, when studying the psychophysiological principles underlying human function during [stressful] job performance, specialists use the data obtained to improve aviation technology, increase the reliability and efficiency of performance, standardize jobs, and optimize instruction and training. When studying flight performance, they have identified the physiological reactions that occur over the course of a flight, the nature of job demands, and the characteristics of the interaction of the pilot with display systems and other flight equipment.

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This handbook includes 37 chapters grouped according to major area, each with a reference list and subject index. The psychophysiological section is subdivided into 2 parts. The first is devoted to scientific justification for the major specifications for various technical systems and devices to support effective performance and flight safety. The second part deals with efficient work organization and development of measures to improve the health and maintain the work capacity of flight personnel and other specialists, as well as their psychophysiological readiness for complex task performance.

The proposed system for subdividing aviation medicine is adequately justified. Human psychological capacities, work conditions, therapeutic measures, state of health, performance level -- all these elements are intimately related. There exists a direct connection between a pilot's psychophysiological state, the completeness and accuracy of his psychological representation of the flight situation, and the reliability of his performance, appropriateness of his judgements, accuracy of his recognition of incoming signals, and quality of his decisions.

The authors identify two techniques for increasing the psychophysiological reliability of pilot performance. The first involves designing flight tasks to accord with the psychophysiological capabilities of flight personnel. The second involves expanding the functional capabilities and enhancing the psychophysiological resources of these personnel through special training and psychological and hygienic measures.

Great emphasis is placed on the medical flight certification exam and the important clinical aspects of aviation medicine that actively facilitate medical support of flight performance.

The handbook presents a new approach to the utilization of pharmacological measures in the practice of aviation medicine. The literature in this area consists of a relatively small number of works with practical recommendations for flight physicians. The authors believe that drugs can solve a number of problems, including mobilizing psychophysiological functions, increasing work capacity for operator tasks, decreasing fatigue, attenuating the buildup of extreme emotional reactions, inducing optimum levels of reactivity, etc. All of these benefits are extremely critical and promising, but additional research and legal groundwork are required to develop specific, scientifically justified practical recommendations for aviation medicine.

This handbook emphasizes issues related to engineering psychology and ergonomics, directed at improving flight performance. It is well known that, even after instruction, an operator may not fully realize the potential inherent in a technology, especially when an individual is compelled to work at the limit of his physical and psychological resources and, in particular, while being exposed to adverse environmental factors, insufficient information, and time pressure.

The efficiency of a person's use of a technology depends, to a great extent, on the degree to which it is congruent with the purpose of his activity, environmental conditions, and his own psychological capabilities.

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The authors have formulated the goals of aviation engineering psychology as follows: to create psychologically justified specifications for information representation systems, control devices, and dynamic systems parameters; to develop methods for researching the characteristics of human psychological activity in order to increase reliability and efficiency of flight vehicle control; to develop psychologically justified principles for assigning functions to humans and automated systems.

Chapter 23, concerning pilots' spatial orientation is more thorough than found in other handbooks of aviation medicine. In recent years, little has been written on spatial disorientation and illusions that develop during flight. Some pilots and flight physicians believe that the increased number of flight and navigation instruments with improved reliability in spatial orientation tasks, have obviated the necessity to study spatial disorientation in pilots. However, at the same time the number of potential and actual flight accidents attributable to spatial disorientation is relatively great. It is possible that the majority of aviation accidents occurring for "unknown reasons" are in some way associated with pilot spatial disorientation during flight. This chapter describes the known mechanisms underlying spatial disorientation and techniques for preventing this phenomenon in flight, an important area of consideration in the medical support of flights and analysis of actual and potential flight accidents.

It should be noted that, overall, the guidebook is written in understandable language and will be useful to flight physicians and to scientists working in the area of aviation medicine. However, some chapters contain some technical language and discussion at a level suitable only for highly trained specialists and not for the general practitioner.

Discussion of specific criticisms of the book omitted.

The handbook does not devote sufficient attention to specific issues of hygienic selection of decorative polymer materials for planes and helicopters, nor to evaluating and monitoring their use. Little attention is paid to the methods for evaluating toxicity of burning polymer materials, fire-fighting and prevention procedures following an accident, or new methods for rodent extermination on aircraft (although the old method is discussed adequately).

Insufficient attention is given to standardization of work and rest schedules (especially, for long flights). The handbook should have presented more information on the jobs of controller personnel, and on medical support of modern helicopters.

In our age of rapid technological progress and urbanization it is important to discuss problems of environmental protection, particularly the legal requirements in the USSR law on protecting the atmosphere, adopted in 1981. It would have been desirable to provide information describing the maximum acceptable level for disposal of waste materials resulting from aviation enterprises and protection of bodies of water in the vicinity of airports.

Paragraph omitted.

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In spite of these shortcomings, this handbook makes an important contribution to aviation medicine. It reflects the modern state of the art. Flight physicians and scientists will find answers to many important theoretical and practical questions in its pages.

In conclusion, it should be emphasized that the authors of this handbook have performed a real service in producing our first complete and comprehensive handbook of aviation medicine.

BIOLOGICAL RHYTHMS

(See also: Biospherics M129; Psychology M130)

PAPERS:

P819(18/88) Shukin AI.

The phenomenon of group synchronization of biological rhythms in single and double shift work.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 212-213.

Biological Rhythms

Humans, Males, Workers

Human Performance, Shift Work, Group Coordination; Psychology, Stress

Abstract: The authors studied circadian rhythms in humans working on a double-shift schedule. This is a timely issue because of the increased proportion of double-shift work in the economy and the future organization of work shifts on long-term space flights.

Factory workers (men aged 18-21) who had been working for 2 months to 2 years participated in this study. One group of subjects worked only the morning shift (from 0800 to 1700), while the other worked morning and evening shifts (from 1700 to 0100) on alternating weeks. The following functional parameters were measured at 2 hour intervals from 7 a.m. to 7 a.m. of the following day: heart rate, rectal, oral, and underarm body temperatures; renal excretion of potassium and sodium; diuresis; and potassium-sodium ratio. Subjects were awakened during the night to measure these parameters. A total of 6305 measurements were made on a total of 74 subjects.

Analysis of results included graphic representation of mean group diurnal curves, evaluation of the amplitude of diurnal rhythms in the parameters studied, position of the acrophase in Moscow time, numerical value of parameters in the acrophase, determination of the magnitude of phase angles between diurnal maxima (and minima) of various functional parameters, and statistical testing of results using nonparametric tests.

Under double shift schedules, as opposed to single-shift schedules, the diurnal dynamics of heart rate, body temperature, renal excretion of potassium and sodium showed agreement among individuals: curves of different individuals were similar with respect to position of the maximum on a 24-hour scale, and also with respect to the nature of mutual phase synchronization. Individual differences in biological rhythms were much clearer under conditions of single shift work than in the double-shift situation. This effect was called the phenomenon of group synchronization of diurnal periodicity in functional parameters. The authors explain this

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phenomenon with reference to the characteristics of the body's circadian rhythms, which under the double-shift schedule were more pliant and sensitive to the synchronizing effect of the work schedule; than under the single-schedule. This is not surprising, because on the former schedule the circadian rhythm had to undergo restructuring every week, causing it to become more responsive to the synchronizing effects of the work-rest schedule, and possibly other exogenous synchronizers as well. The circadian rhythm in effect forsook its individuality in order to better mobilize the body's working resources during working hours. When subjects always worked the day shift this did not occur. Here, physiological support of work performance was combined (not completely, but more than in the double-shift situation) with retention of individual differences in biological rhythms. However, any subjugation of the individual to common requirements leads to stress. Thus, there is reason to associate synchronization of diurnal periodicity in vital functions found in this study with signs of stress associated with the double-shift schedule.

An analogous phenomenon, synchronization based on precise coincidence of increased and decreased activity in a stressful situation, has been described with regard to various organs (interorgan synchronization) and cellular groups functionally united in a single organ (intraorgan synchronization).

BIOSPHERICS

MONOGRAPH

M129(18/88) Agadzhanyan NA.
Chelovek i biosfera [Man and the biosphere.]
Moscow: Znaniye; 1987.
[96 pages]

KEY WORDS: Biospherics, Biological Rhythms

Annotation: The profile of our planet is changing. However, nature and the biological characteristics of the human body cannot change at rates equal to those of scientific and technological progress. Can the human body adapt to constantly changing conditions? How could this be facilitated? What are the roles of biological rhythms in human vital functions? The reader will find answers to these and other questions in this book, which is intended for students in adult education courses in natural sciences and also a broad range of readers.

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BODY FLUIDS

(See also: Metabolism P825; Space Biology and Medicine M125;
Special Feature M856)

PAPERS:

P836(18/88)* Denisova LA, Lavrova YeA, Natochin YuV, Serova LV.
Concentrations of fluid and electrolytes in organs and tissues of male rats after flight on the COSMOS-1667 biosatellite.
Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.
22(2): 33-37; 1988.
(17 references; 3 in English)

Body Fluids, Fluid-Electrolyte Concentration
Rats, Males; Reproductive Biology, Female, Pregnant; Sex Differences
Space Flight, COSMOS-1667, COSMOS-1514

Abstract: Subjects in this experiment were a total of 21 3-month-old Wistar rats, of which 7 (group 1) were flown aboard COSMOS-1667 for 7 days, 7 were maintained in a mock-up of the satellite and exposed to all space flight factors except weightlessness (group 2) and 7 (group 3) constituted a vivarium control. After reentry, a kidney and pieces of the liver, myocardium, skin, tibia, and reproductive organs, testes and epididymus were isolated from sacrificed animals. These samples were dried and fluid content measured, then the organic substance was dissolved. Concentrations of Na and K were measured in an air-propane flame with a photometer, while concentrations of Ca and Mg were measured using an atom absorption spectrophotometer in an air-acetylene flame.

Total body weight of flight rats did not decrease during the flight period. Kidney weight was no different from that of the synchronous group, but did exceed that of the vivarium control. However, concentrations of K, Na, and Mg were lower in group 1 than in group 3. No effects were found in the liver. Although myocardial weight was not significantly affected by space flight, this organ showed less hydration and lower K concentration than that of controls. Animals in the flight groups showed increased K in the tibia and skin, with Na elevated in the skin alone. No significant effects were observed with regard to the weight of the testes or epididymus. However, hydration of the tail of the epididymus was higher in the flight group. Concentration of NA was lower in the testes of flight animals, while concentration of K was higher. Differences in hydration and minerals of the head and tail of the epididymus characteristic of rats in the norm, were diminished in flight rats.

When results with these male rats were compared to results with pregnant females flown on COSMOS-1514, significant differences were found. Pregnant females showed effects of flight on calcium metabolism, while this parameter was unaffected in males, which instead displayed altered K metabolism. The authors conclude that changes in fluid-electrolyte homeostasis in response to space flight are relatively rapid, occurring as early as the first 5-7 days of flight. Changes in fluid-electrolyte components of tissues occur not only in musculoskeletal organs, but in other organs that do not serve an antigravity function, such as organs of the reproductive system. The data suggest that hormonal status, as well as other characteristics of

BODY FLUIDS

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physiological differences among the sexes of mammals, have a substantial effect on the response of animals to space flight factors, as expressed in differences in changes in fluid-electrolyte components of male and pregnant female rats.

Table 1: Fluid-electrolyte composition of visceral organs of rats after a 7-day flight on a biosatellite

Organ	Organ, g	Water, g per 1 g dry substance	Electrolytes, mequiv. per 1 g wet substance			
			Na	K	Ca	Mg
Liver						
1(7)	11.0	2.17	33.6	87.1	5.1	22.9
2(7)	12.9	2.20	32.4	85.7	6.6	18.6
3(5)	10.6	2.17	34.6	84.4	2.8	20.2
p(1-3) < 0.05						
Kidney						
1(5)	1.24	3.17	71.5	61.7	3.6	14.5
	p(1-3) < 0.001		p(1-2) < 0.01	p(1-2) < 0.001		p(1-2) < 0.01
2(7)	1.17	3.35	80.0	72.1	3.3	16.8
	p(2-3) < 0.05			p(1-3) < 0.001		p(1-3) < 0.05
3(6)	1.00	3.33	77.1	69.9	3.7	15.7
Myocardium						
1(7)	0.96	4.13	58.7	54.8	4.0	20.5
		p(1-2) < 0.05		p(1-2) < 0.05		
2(7)	1.01	4.67	62.0	63.1	7.1	23.0
3(5)	0.97	4.63	55.4	60.5	3.0	20.2
Skin						
1(6)	—	1.29	78.1	39.8	5.2	9.6
			p(1-2,3) < 0.001		p(1-2,3) < 0.001	
2(5)	—	1.44	63.1	27.3	4.9	7.9
3(6)	—	1.45	62.6	29.0	6.9	8.3
Bone						
1(6)	—	0.27	257	25.8	7554	310
				p(1-2,3) < 0.05		
2(7)	—	0.31	266	22.6	—	310
3(5)	—	0.27	275	21.1	8733	327

BODY FLUIDS

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Table 2: Parameters of reproductive organs in male rats after a 7-day space flight

Group	Testes Weight		Epididymus weight		Testes weight:	Spermatozooids
	g	% body wght	g	% body wght	epididymus wght	in 1 g epid. (millions)
1(6)	2.71	0.82	0.75	0.23	3.6	168
3(5)	2.71	0.82	0.75	0.23	3.6	147

Table 3: Fluid-electrolyte composition of reproductive organs of male rats after a 7-day space flight

Organ	Water, g per 1 g dry weight	Electrolytes per 1 g wet substance			
		Na	K	Ca	Mg
Testes:					
1(6)	6.55	57.7	83.3	2.75	13.9
		p(1-2)<0.05		p(1-2,3)<0.001	
2(5)	6.49	64.5	60.9	2.71	15.7
3(5)	6.59	64.8	65.6	3.0	14.5
Head of the Epididymus:					
1(6)	2.79	62.5	41.9	3.3	13.6
2(4)	2.80	64.9	34.6	4.1	12.7
3(4)	2.87	64.6	34.5	3.7	12.5
Tail of the Epididymus:					
1(6)	2.92	54.2	42.8	3.9	12.8
	p(1-2)<0.05				
	p(1-3)<0.01				
2(4)	2.45	60.4	39.3	—	13.8
3(4)	2.37	55.8	42.3	—	14.7

P854(18/88)* Kondratyuk VA, Gnatyuk MS, Volkov KS.

Structural reorganization of the liver in response to exposure to reclaimed drinking water with varying concentrations of sodium and potassium ions.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 87-90 ; 1988.

(9 references; none in English)

Body Fluids, Liver Structure

Rats, Male

Life Support Systems, Reclaimed Water, Sodium, Potassium

Abstract: A 12-month experiment was performed on 190 outbred male rats. The animals were maintained in a vivarium and fed the usual rations. Control animals (1) drank tap water with 24-33 mg/l Na, 3.2-4 mg/l K, and 500 mg/l total minerals. The experimental animals drank water produced by a reclamation system with total minerals of 100 mg/l. Group 2 received the reclaimed water, group 3 the water with 100 mg/l Na supplement, group 4 the water plus 10 mg/l K. The remaining groups had supplements of both Na and K with respective concentrations of 100 and 10 mg/l for group 5, 75 and 7.5 mg/l for group 6, 50 and 5 mg/l for group 7, and 25 and 2.5 mg/l for group 8. After 12 months the animals were sacrificed and pieces of the liver prepared for histological, histochemical, and electron microscopical analysis.

Morphological damage was noted in the livers of animals receiving 100 mg/l Na, 10 mg/l K, or both. Animals receiving 75.0 mg/l Na, 7.5 mg/l K, or both showed only insignificant changes. The organ remained in an adequate functional state. Animals receiving lower doses of minerals showed no liver damage.

Figure 1: Ultrastructure of hepatocytes of rats drinking water with 100 mg/l Na.

Figure 2: Ultrastructure of hepatocytes of rats drinking water with 10 mg/l K

Figure 3: Ultrastructure of hepatocytes of rats drinking water with 100 mg/l Na and 10 mg/l K

CARDIOVASCULAR AND RESPIRATORY SYSTEMS

(See also: Adaptation P857; Metabolism P825;
Space Biology and Medicine M125; Special Feature P856)

PAPERS:

P833(18/88)* Iseyev LR, Mednykh AY, Vorob'yev VYe, Abdrakhmanov VR.
**CO₂ sensitivity of the respiration regulation system under conditions
simulating space flight**

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 16-20 ; 1988.

(13 references; 2 in English)

Cardiovascular and Respiratory Systems, Respiration Regulation
Humans, Males

Space Flight Simulation, Isolation, Hypokinesia with Head-Down Tilt,
Hypercapnia

Abstract: Studies were performed on 3 apparently healthy men who were isolated for 366 days in hermetically sealed living quarters, with an atmosphere of normal pressure and oxygen level. Because of the details of the air purifying system, there was always a surplus of 1-1.5% CO₂ in the air, and during a period simulating an emergency situation during months 8 and 11 of the treatment, CO₂ concentration increased to 3%. An additional experiment was conducted using 53 apparently healthy men, aged 21 to 48, who were subjected to hypokinesia with head-down tilt for 7-120 days. All sessions in the baseline and isolation conditions were performed with subjects in horizontal position, while those in the hypokinesia period were performed on subjects in head-down position. The goal of the experiments was to measure the CO₂ sensitivity of the system regulating respiration (SSRR). Changes in this system were measured using rebreathing. After several minutes of rebreathing, the partial pressure of CO₂ in the breathing volume is equal to that of mixed venous blood. A subject was connected to a spirometer with the CO₂ absorbent removed. Both a spiograph and a capnograph were used to register parameters during rebreathing. Pulmonary ventilation was computed as a linear function of partial pressure of CO₂ in alveolar air. The point at which pulmonary ventilation equals zero, the apnea point, considered to be the threshold of sensitivity, was computed by extrapolating this function. The slope of the function was considered a measure of the excitability of the respiration regulation function.

As subjects spent longer periods in the isolation chamber, the apnea point occurred at greater values of alveolar CO₂. After emergence from isolation this parameter normalized. Slope of the function (a measure of excitability) increased in two subjects and decreased in one during isolation. These changes are described as results of adaptive mechanisms serving to maintain homeostasis during long-term exposure to hypercapnia. Values of these parameters fluctuated during head-down tilt. Threshold of sensitivity decreased after 7 days at -12°. At -8° sensitivity increased in one case and decreased in another, becoming normal at 21 days. Starting at 75 days at -4°, the sensitivity threshold increased. Excitability did not alter significantly during hypokinesia.

CARDIOVASCULAR AND RESPIRATORY SYSTEMS

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Table 1: Sensitivity of the respiration regulation system to CO_2 in a year long experiment in a hermetically sealed chamber

Table 2: Sensitivity of the respiration regulation system to CO_2 during hypokinesia with head-down tilt varying in duration.

P839(18/88)* Stazhadze LL, Borob'yev VYe, Repenkova LG, Kovachevich IV, Ivchenko VF, Kal'yanova VN.

Clinical and physiological aspects of oxygen supply to tissues in the human body under conditions of hypokinesia with head-down tilt.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 45-49 ; 1988.

(20 references; 3 in English)

Cardiovascular and Respiratory Systems, Tissue Oxygenation
Humans, Male
Hypokinesia with Head-Down Tilt

Abstract: Twenty-four apparently healthy men were examined during a baseline period, on days 3 and 10 of a 14-day period of hypokinesia with head-down tilt (-8°) or on day 30 of a 120-period of hypokinesia with head-down tilt (-4°). Arterial blood was taken from the radial artery and venous blood from the ulnar vein. Oxygen pressure was measured in both samples and buffer base deficit, a parameter which provides information about the metabolic component of acid-base balance, was computed for venous blood. A formula was used to compute concentration of oxygen in venous blood. At the same time, impedance plethysmography of the right lung was performed and an index reflecting rate of blood perfusion of the upper, middle and lower portions was computed. Dicrotic and diastolic indices, providing information about the tonus of arterioles and veins, and α/T reflecting tonus of vessels of moderate and large caliber were also computed. An EKG was recorded from 12 leads. "Integral impedance plethysmography" was used to study cardiac ejection and peripheral vascular resistance. Concentration of 2,3-diphosphoglycerine (2,3-DPG) was measured in venous erythrocytes and concentration of inorganic phosphate was measured in venous blood. Lactate concentration was also measured. All measurements were made while patients were at rest.

Studies performed during the first week of hypokinesia showed decreased oxygen pressure in arterial blood compared to baseline levels. This difference became significant on day 10. At the same time, the alveolar-arterial oxygen gradient decreased. Similar results were obtained for day 30 of treatment. While blood perfusion of the upper and middle portions of the lung increased, this parameter decreased significantly in the lower lung. Cardiac ejection decreased significantly by the end of the first week of hypokinesia, leading to decrease in partial oxygen pressure in capillaries of the systemic circulation tract and in venous blood. At the same time, peripheral vascular resistance gradually increased, and heart rate decreased. The authors conclude that during the first 2 weeks of hypokinesia with head-down tilt diminished oxygen supply to tissues is associated with decreased cardiac ejection. However, there is also a purely respiratory component to these effects, linked to disruption of ventilatory-perfusion phenomena in the lungs. This was reflected in an increase in the difference between oxygenation of arterial and venous blood. During the initial period of hypokinesia this difference increased due to a decrease in oxygen in venous blood. However, on day 30 of the treatment, the artery-vein difference was significantly below baseline. Thus, it is appropriate to speak of increased oxygen consumption during the first 2 weeks of hypokinesia and a subsequent decrease during the second 2 weeks. These results suggest the possibility of inadequate oxygen supply to tissues during the initial hypokinesia period. Evidence relating to this issue

P839

includes the tendency for inorganic phosphate, a product of anaerobic metabolism, to increase in venous blood. However, evidence of acidosis (buffer base deficit) did not occur until day 30 of treatment. Concentration of 2,3-DPG is another indicator of tissue hypoxia; this parameter did tend to increase during the treatment and was significantly above baseline on day 30. The authors conclude that hypokinesia with head-down tilt is associated with the development of circulatory and respiratory hypoxia with signs of decompensation, as evidenced by development of secondary tissue hypoxia starting at the beginning of the treatment and reaching maximum value on day 30. Since demand for oxygen may increase under space flight conditions, of which the experimental treatment is a simulation, e.g, due to exercise, the authors recommend oxygen therapy.

Table: Changes in parameters in response to hypokinesia with head-down tilt

Parameter	Baseline	Day of Hypokinesia		
		3	10	30
p_{aO_2} , mm Hg	95.7 (24)	88.9 (12)	86.7* (12)	86.2* (12)
P_{AaO_2} , mm Hg	8.1 (24)	10.3 (12)	14.8 (12)	16.7 (6)
C_{VO_2} , %	4.7 (20)	4.0 (20)	3.8* (19)	6.7* (12)
Lactate, mmole/l	1.50 (12)	2.07* (12)	1.93 (12)	1.83 (12)
Inorg. phosphate, μ mole/l	4.29 (24)	5.36 (12)	4.98 (12)	5.20* (12)
2,3-DPG, μ mole/l	3.12 (24)	3.57 (12)	3.42 (12)	4.15* (12)
Base deficit, mmole/l	- 0.7 (24)	-1.0 (12)	-0.7 (12)	-3.3* (12)

Numbers in parentheses refer to number of observation.

* Difference from baseline significant, $p < 0.05$.

P846(18/88)* Lobanok LM, Kiriienko AYe.

Effects of hypoxia and reoxygenation on the contractility of the isolated heart of rats varying in age.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 70-72 ; 1988.

(10 references; 2 in English)

Cardiovascular and Respiratory Systems, Cardiac Contractility

Rats, Age Differences

Hypoxia, Reoxygenation

Abstract: This study used the isolated hearts of a total of 60 white rats in two age groups: 8-10 months (mature) and 24-26 months (old). Hearts were isolated and placed in a solution in which oxygen pressure was lowered for 30 minutes to 100 mm Hg, followed by a 30-minute period of reoxygenation, followed by 5-minute periods of successively lower oxygenation of 500, 400, 300, 200, 100, and 50 mm Hg, with 10 minute periods of reoxygenation after each "step." Hearts were stimulated with electrical current and the following parameters recorded: heart rate, systolic and diastolic blood pressure in the left ventricle, rate of increase and decrease to the maximum developed pressure and time of half relaxation, contractility and relaxation index of the myocardium, and minute coronary blood flow volume.

Age-related changes in cardiac response to hypoxia included less development of myocardial contraction in response to decreased oxygen pressure in a perfused solution, and more rapid and complete recovery of functions disrupted by hypoxia in older individuals. Because glycolysis is known to be more pronounced in the myocardium of older subjects the authors conjecture that decreased pO_2 in the solution induced a smaller energy deficit in the myocardia of these subjects and thus less functional disruption. However, this compensation would only be adequate for less severe degrees of hypoxia. Another possible reason for these results is the decreased capacitance of the sarcoplasmic reticulum in older subjects, leading to lower accumulation of calcium around the myofibrils and thus decreased hypoxic contraction of the myocardium.

Figure 1: The effect of hypoxia and reoxygenation on systolic pressure in the left ventricle of the isolated heart of mature and old rats

Figure 2: Changes in systolic blood pressure and minute volume of coronary blood flow in response to hypoxia and reoxygenation of the isolated hearts of mature and old rats.

Figure 3: Changes in rate of increase of blood pressure in isolated hearts of mature and old rats in response to stepwise decrease of p_2 in a solution alternating with periods of reoxygenation

CYTOLOGY

(See also: Space Biology and Medicine: M125)

PAPER:

P823(18/88) Butey M. (Paris)

Preliminary results and prospects in the study of the effects of microgravity on cell biology.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 309.

Cytology, Cell Biology; Neurophysiology, Cerebellar Neurons
Rats, Developmental Biology, Embryos; Hybridoma
Space Flight, COSMOS-1514; Clinostatting

Abstract: The author's laboratory conducted a number of experiments to study the effects of microgravity on cell biology, as related to the possibility of pathological processes occurring in humans and animals on long-term space flights.

As part of a collaboration between the National Institute of Health and Medical Research of France and the USSR Ministry of Health (Krasnov, Viktorov, Privat, Dupuy-Coin), research was conducted which made it possible to identify changes in size and number of neurons in the central lobe of the cerebellar vermis of rats after a 5-day flight on board COSMOS-1514 biosatellite. When cells from the cerebellum of rat embryos were cultured after the flight, no anomalies were found.

At present, an analogous study is being performed by Konstantinova, Fuchs, Bykovskiy, and Nefussi. Its goal is to determine the role of bone tissue cells in the mechanism of decalcification.

During the last D-1 flight (NASA, CNES, DFVLR), the author's laboratory conducted an experiment on the cells of a hybridoma, which was one of 14 experiments in cell biology. The cells retained their viability throughout the flight, and developed successfully under normal cultivation conditions postflight. Preliminary results indicate some activation of the growth of flight cells compared with the control. Samples, fixed in flight in glutaraldehyde, are now being studied by 3-dimensional reconstruction and computer imaging.

Dr. Brigleb (DFVLR) and the author are currently studying the effect of weightlessness, simulated by rapid clinostatting on hybridoma cells. The experimenters have observed unexpected differences between the experimental and control conditions.

DEVELOPMENTAL BIOLOGY: See Adaptation P822; Cytology P823; Psychology M130

ENDOCRINOLOGY

(See also: Adaptation P857; Metabolism P829; Psychology M130;
Special Feature P854)

PAPERS:

P834(18/88)* Shubnikova YeA, Dobryakova AV.

Ultrastructure of the submandibular glands of rats in weightlessness.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 20-26 ; 1988.

(9 references; 2 in English)

Endocrinology, Salivary, Submandibular Glands

Rats

Space Flight, COSMOS-1667

Abstract: The ultrastructure of the submandibular salivary glands was studied in 100-day old male Wistar rats exposed to space for 7 days on the COSMOS-1667 biosatellite. The subjects were sacrificed 4-8 hours after reentry. One month later animals in a control condition were housed for 7 days on a mockup of the biosatellite. A vivarium control was also used. The glands studied were isolated and fixed for study by light and electron microscopes.

Light microscopy revealed no significant differences between the synchronous control and flight groups; both groups showed signs of hyperemia. Electron microscopy revealed the following changes in the acini: chromatin condensation, darkened cells and nuclei, electron dense vacuoles, fragmentation of granular endoplasmic reticulum, enlargement of interstitial space, acini lumens, and intercellular canaliculi, loosening of basal membranes, and thinning of capillary walls. Synchronous control animals showed chromatin condensation in nuclei and fragmentation of the granular endoplasmic reticulum like the flight group, demonstrating inhibition of synthesis and excretion of salivary protein. However, only the flight group showed increased excretion and, probably also secretion, of water and electrolytes. Granulocytes in animals of both groups revealed enlargement of secretory granules; effects in flight animals were more extreme. Swelling of the mitochondria was most pronounced in the synchronous control group. These animals also displayed mitochondrial swelling in the striated area.

The authors conclude that space flight factors are associated with signs of hypersalivation, increased secretion and reabsorption in acini, while synthesis and excretion of the protein component of saliva are retarded. After ground-based simulation of all space flight conditions except weightlessness, there are signs of inhibition of all components of the protein synthesizing apparatus of acinary cells. However the resemblance between the flight and synchronous groups is attributed to nonspecific inhibition of protein synthesis in response to stress. In the synchronous condition signs of increased secretion, reabsorption, and salivation are not marked; at the same time, this group shows signs of attenuation of the reabsorption function of the striated area. Enlargement of interstitial spaces, loosening of the basal membrane and thinning of capillary walls

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attest to increased vascular permeability, not observed in the synchronous group. These differences are attributed to gravitational stress after adaptation to weightlessness.

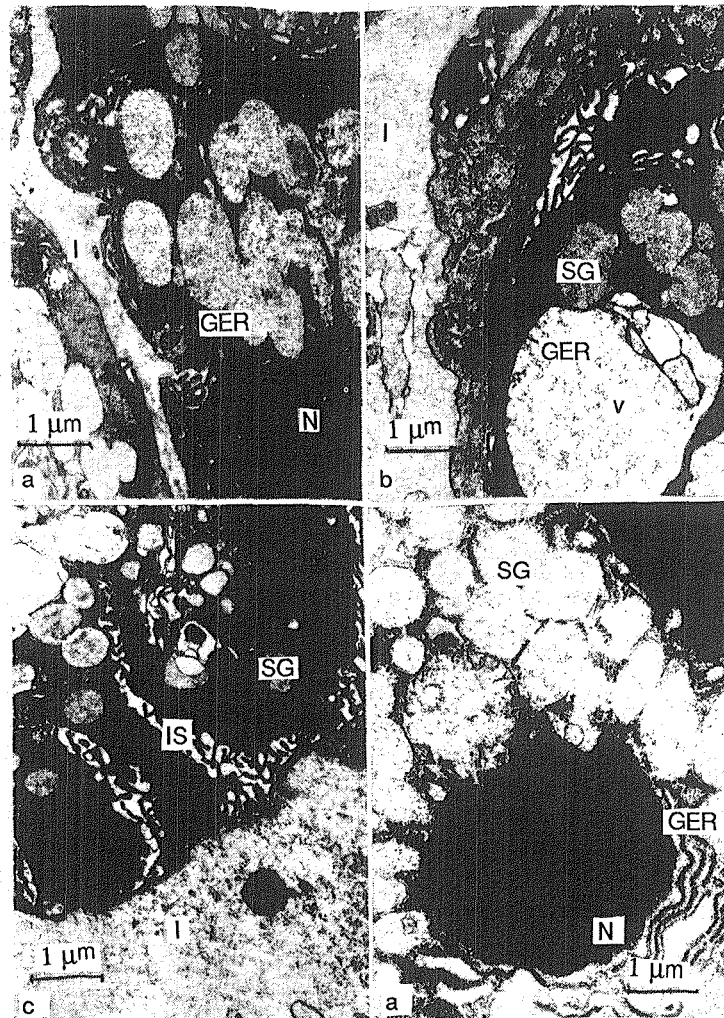


Figure 1. Ultrastructure of cells in acinous area of the submandibular glands of rats in the control and flight groups

a - acinous section of the submandibular salivary glands in a control rat. The nucleus contains chromatin with a moderate degree of condensation, unenlarged interstitial space, and granular endoplasmic reticulum in the shape of parallel cisterns. Mag. 16000; b and c -- acini of the submandibular salivary glands after flight. Induration of the granular endoplasmic reticulum and cytoplasm matrix, appearance of large vacuoles, enlargement of interstitial space filled with fine fibrillar material, enlargement of intercellular space, induration of secretion in secretory granules. Mag. 16,000. d -- acinous cell of the submandibular salivary gland after the synchronous experiment. Overflowing of merging secretory cells with nondense material, fragmentation of the cisterns of the granular endoplasmic reticulum, containing dark material, chromatin condensation in the nucleus. Mag. 16, 000.

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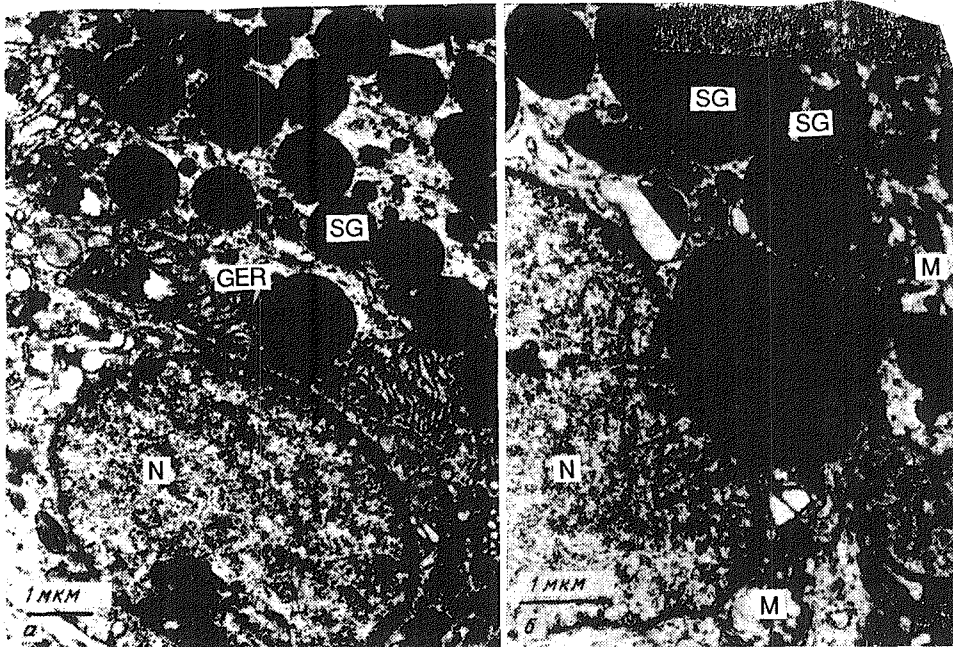


Figure 2. Ultrastructure of cells of the granular section of the submandibular salivary glands of rats in control and experimental groups.

a - cell of the granular area of the submandibular salivary gland of a control rat. Granules are small, mitochondria unswollen. Mag. 12,000; b - cells of the granular area of the gland after flight. Very large and very small granules, swollen mitochondria. Mag. 12,000.

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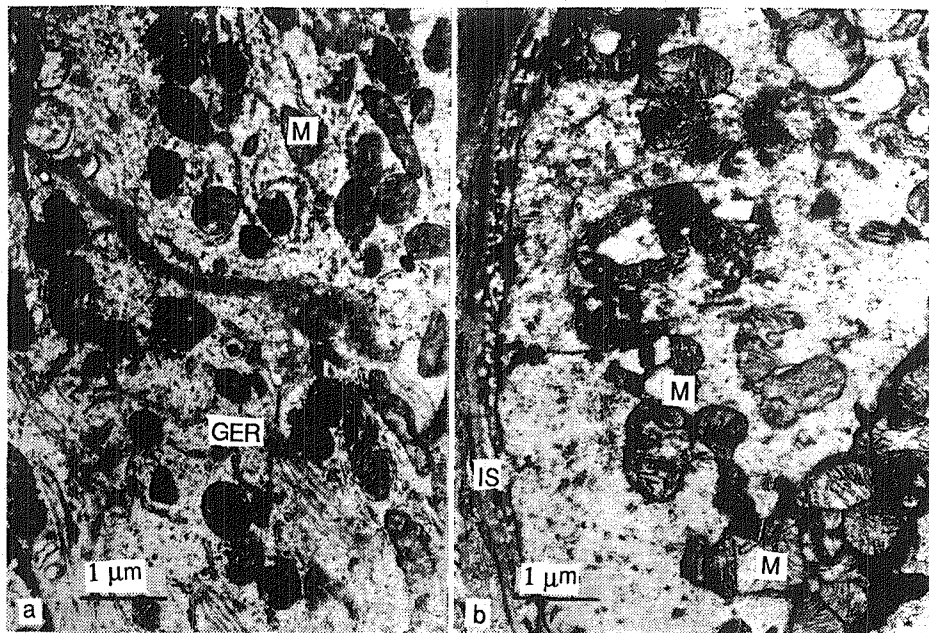


Figure 3: Ultrastructure of cells in the striated area of the submandibular salivary glands of rats in control and experimental groups.

a - cells of the striated area of a control animal. Mag. 16,000.; b - cells of the striated area of the submandibular glands after the synchronous experiment. Swelling and destruction of the mitochondria, filling of the interstitial spaces with dark, homogenous material. Mag. 16,000.

Key: N - nucleus, GER - granular endoplasmic reticulum, V - vacuoles, IS - intercellular spaces, SG - secretory granules, M - mitochondria; I - interstitial space.

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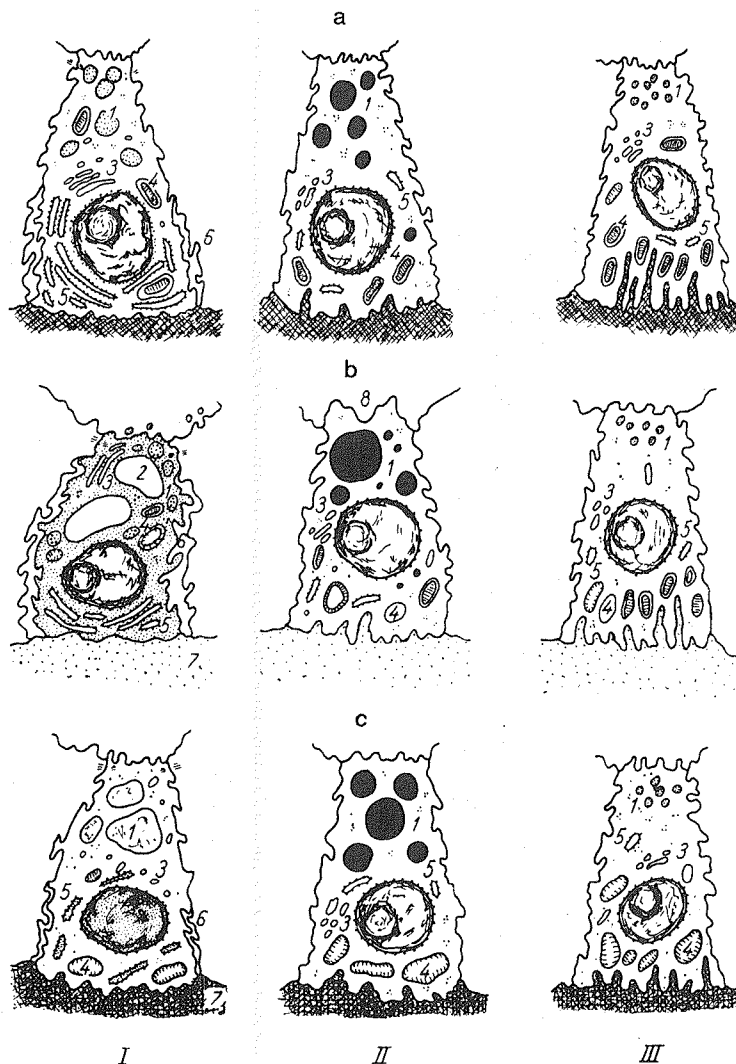


Figure 4: Changes in specialized elements of the submandibular salivary glands of rats after the flight and synchronous experiments.

a - control; b - flight experiment; c - synchronous experiment. I - III - respectively, the acinous, granular, and striated areas: 1 - secretor granules; 2 - electron-transparent vacuoles; 3 - Golgi complex; 4 - mitochondria; 5 - granular endoplasmic reticulum; 6 - intercellular canaliculi; 7 - basal membrane; 8 - swelling of the apical portions of the cells of the granular area in the lumen.

P835(18/88)* Plakhuta-Plakutina GI, Dmitriyeva NP, Amirkhanyan YeA.
The thyroid C-cell system in rats after space flight on the COSMOS-1667 biosatellite.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 26-32 ; 1988.

(15 references; 5 in English)

Endocrinology, Thyroid, C-Cell Systems

Rats, Male

Space Flight, COSMOS-1667

Abstract: Seven male Wistar rats were flown for 7 days on the COSMOS-1667 biosatellite. One animal was sacrificed 4 hours after reentry, and the others were sacrificed at subsequent 30-minute intervals. A synchronous control group was housed in a mock-up of the satellite simulating conditions associated with launch and reentry. A vivarium control condition was also used. The right lobe of the thyroid gland was extracted and fixed. Ultrafine sections were examined with an electron microscope. The left lobe was also fixed and a series of 4 μ m sections stained to permit differentiation of folliculi containing iodized thyroglobulin. C-cells were identified by staining with silver nitrate. The functional state of these cells was evaluated by constructing a histogram showing numbers of cells belonging to each of 4 classes, each of which represented a stage in the secretory cycle (determined using an optical grid). The follicular epithelium was measured, as were nuclei of thyrocytes and C-cells.

During the immediate postflight period (4-8 hours after reentry), the structural and functional characteristics of the thyroid exhibited little difference from those of the control groups. The parenchyme consisted mainly of actively functioning follicular cells at various stages in the secretion cycle. This was confirmed by ultrastructure analysis. The dimensions of the follicles, epithelia, and thyrocyte nuclei were similar in the flight and control groups, but colloid staining showed a decrease in iodized thyroglobulins in flight rats. The C-cells in thyroids of flight group rats were either isolated or formed chains along the basal edge of the thyrocytes. There were fewer C-cells in the interfollicular tissue of these rats than in the control animals. In flight rats, C-cells with pooling of secretor granules in the cytoplasm predominated. The number of relatively inactive cells, small and with fine secretor granules, also increased. In addition, some large degranularized C-cells with signs of dystrophic changes were observed. The four types of cells classified were: I - relatively inactive; II and III - cells in synthesis phase; IV - large cells in various stages of degranulation. Thyroids of vivarium control animals were found to contain 15% type I, 59% type II and III, and 26% type IV. Flight group animals had fewer total number of C-cells with an increase in inactive cells and a decrease in proportion of degranulated cells. In addition the nuclei of C-cells decreased in size, confirming that calcitonin synthesis and excretion were inhibited. The synchronous control groups, however, showed no evidence of such a tendency. As reexposure of flight animals to normal gravity increased in duration, C-cells showed signs of increased functional activity. The authors suggest that decreased activity of the C-cell system may be one reason for inhibition of bone formation in weightlessness, combined with the attenuated effects of calcitonin on osteoblasts, and possibly decreased inhibitory effects on osteoclasts.

P835

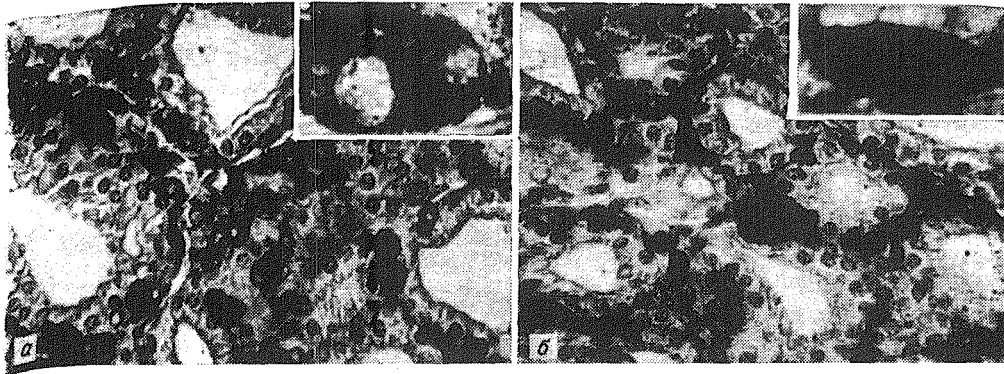


Figure 1: C-cells of rat thyroids after a 7-day space flight.
a - control; b - 5 hours postflight.

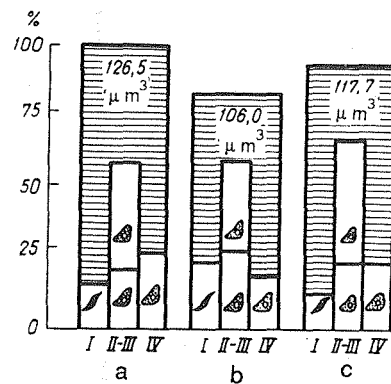


Figure 4: Volume of nuclei (in μm^3) and histogram of C-cells in the thyroids of rats postflight.

I - small, (relatively inactive) cells, II-III - medium cells (synthesis and accumulation of secretor granules), IV - large cells (degranulation). a - control, b - flight, c - synchronous experiment.

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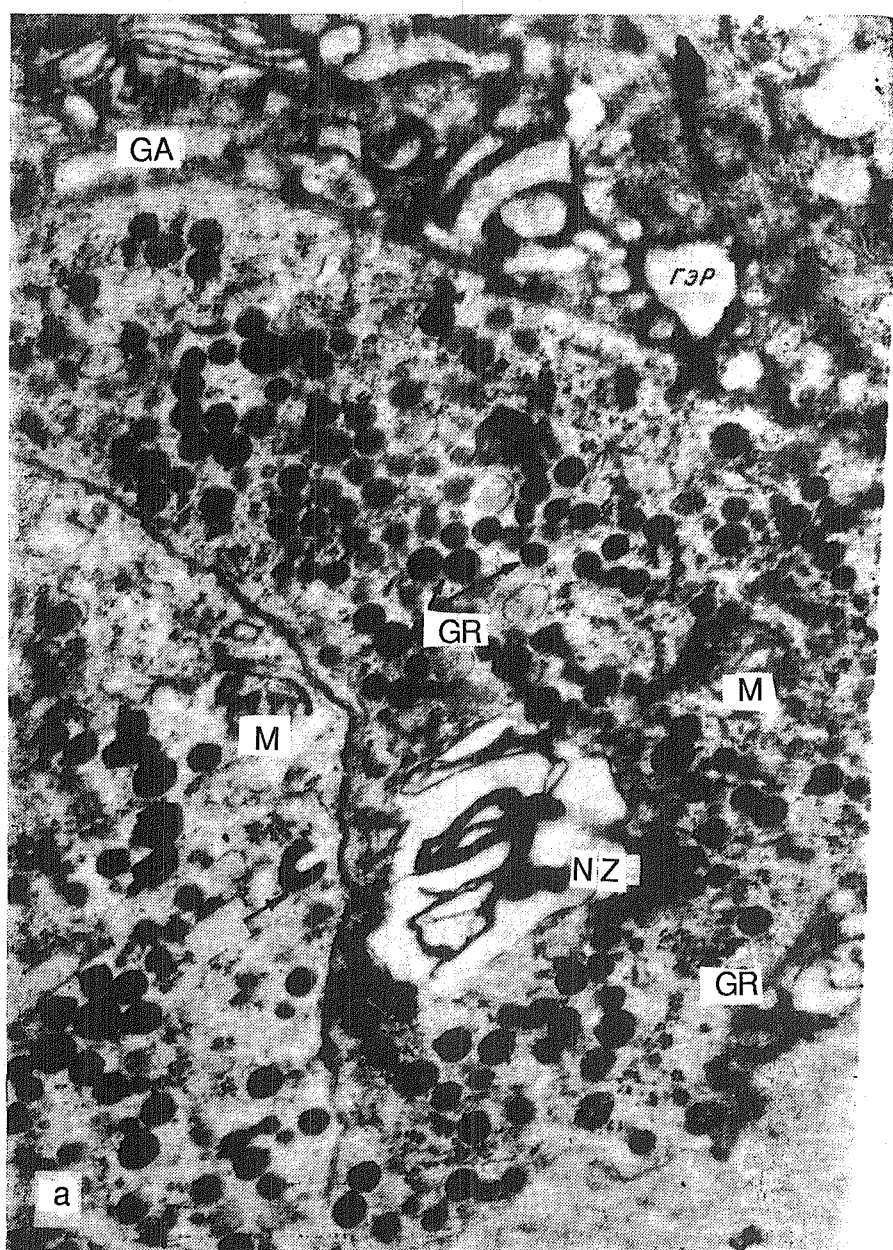


Figure 2 a: Ultrastructure of the thyroids of rats after 7 days of spaceflight. a - C-cells, relatively inactive with pooling of secretion in the granules. One cell has a local area of necrosis (NS) Mag. 25, 000 X.

Abbreviations: GA - Golgi apparatus; GER - granular endoplasmic reticulum; GR - dense granules; M - mitochondria; NZ - necrotic zone

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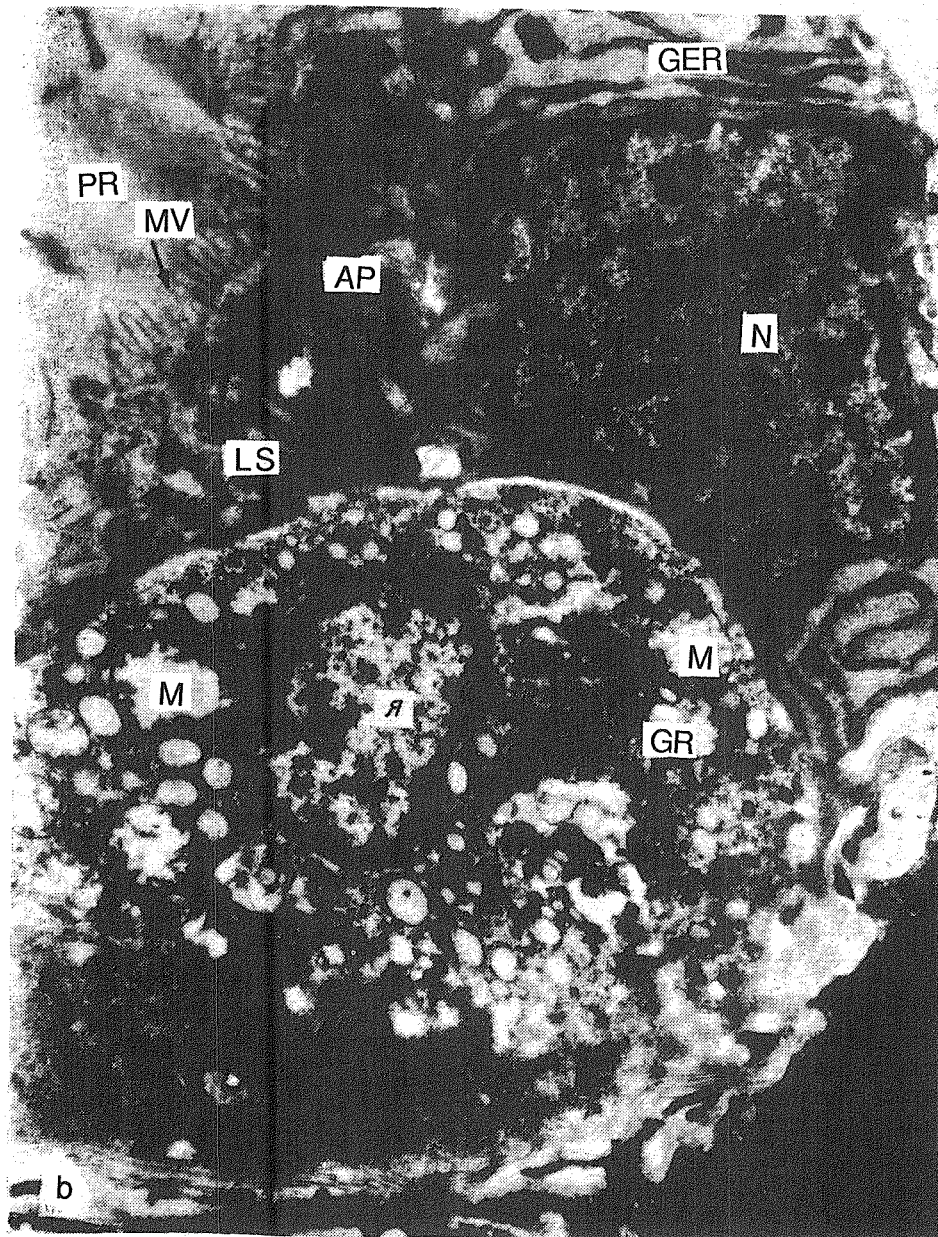


Figure 2 b - Above - follicular cell of typical structure; below - dying C-cell with vacuolized cytoplasm, damaged mitochondria, and small, light nucleus. Mag. 10,000 X

Abbreviations: GR, M, GER - see 2a; AP - apical granule?; LS - lysosome; MV - microvilli; PR - parenchyme; N - nucleus.

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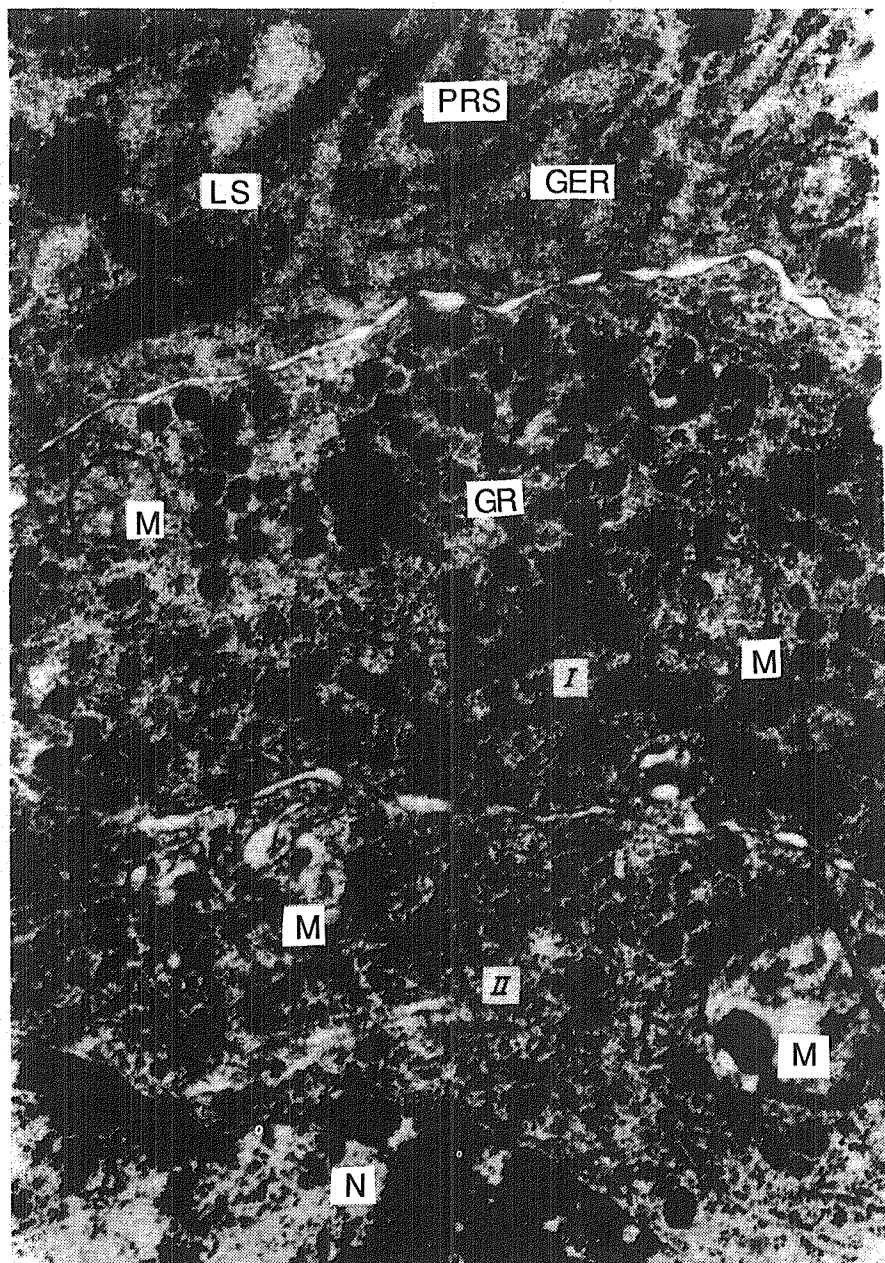


Figure 3: Ultrastructure of the thyroid of control rats. Above - follicular cell; I - C-cell with accumulation of secretor granules; II - C-cell in the degranulation stage. Mag. 25,000 X. For abbreviation key, see Figure 2a and 2b; PS - polyribosomes

ENZYMOLGY

(See also: Gastrointestinal System P830; Metabolism P838; P851)

PAPERS:

P809(18/88) Kukhta VK, Morozkina TS, Listsyna LP, Zakharenko IV, Mal'kovets IG, Karpova IN.

The enzymatic system for initiating and providing protection from [i.e., inhibiting] lipid peroxidation in liver tissue and blood of rats undergoing hypokinesia.

Voprosy Meditsinskoy Khimii.

34(1): 19-22; 1988.

[13 references; 4 in English]

Authors' Affiliation: Minsk Medical School

Enzymology, Metabolism, Lipid Peroxidation, Liver, Blood

Rats

Hypokinesia

Abstract: This work investigated the effects of 1- and 2-month periods of hypokinesia on: concentrations of products of lipid peroxidation; activity of microsomal oxidoreductases that help to initiate lipid peroxidation; activity of superoxide dismutases (SOD), ceruloplasmin, catalases, and glutathione reductases of enzymes, which prevent excess formation and accumulation of lipid peroxidation products. Subjects were a total of 40 rats, of which 10 were controls and 30 were placed in group immobilization cages. The traditional method of immobilization in isolation was not used in order to reduce stress. The mitochondria of the liver were obtained by differential centrifugation, and the remaining liquid centrifuged again to precipitate the membrane fraction of the cytoplasmic net, which was placed in a suspension. Enzyme activity was determined by measuring changes in absorption of electrons by synthetic acceptors when they passed from the oxidized to the reduced form. Donors were $\text{NADPH}\cdot\text{H}^+$ and $\text{NADH}\cdot\text{H}^+$. Superoxide dismutase activity was determined by the color of decolorized tetrazole salts (indicating presence of superoxide anion-radical). Catalase activity was measured by traditional methods and ceruloplasmin activity on the basis of its unique capacity (among blood components) to oxidize certain polyamines. Glutathione activity was measured on the basis of its capacity to reduce oxidized glutathione $\text{NADPH}\cdot\text{H}^+$.

After 1 month of hypokinesia, concentration of lipid peroxidation products, diene conjugates, and MDA were reduced by a mean of 30%. Activity of microsomal $\text{NADPH}\cdot\text{H}^+$ and $\text{NADH}\cdot\text{H}^+$ in the liver increased by more than 150% in the first 30 days of treatment. Activity of SOD, the major enzyme responsible for antioxidation protection of cells, decreased in liver mitochondria by 30% after 2 months of hypokinesia, while its level was unchanged in erythrocytes. Ceruloplasmin, which has the same effect but operates in the blood, increased after 1 month of hypokinesia and normalized after 2 months. Catalase, another important source of antioxidant protection of cells, decreased by 33% after 2 months of hypokinesia. Activity of glutathione reductase was unchanged. The authors conclude that attenuation of enzymatic antioxidant protection of hepatocytes occurring in response to hypokinesia may be an important cause of the increased accumulation of lipid peroxidation products. In addition, the increase in activity of certain microsomal $\text{NADPH}\cdot\text{H}^+$ - and $\text{NADH}\cdot\text{H}^+$ -dependent liver

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oxidoreductases which intensify free radical oxidation of lipids of cellular membranes can lead to increased formation of lipid peroxidation products.

Table 1: Concentration of lipid peroxidation products (in umole/mg of protein) in the liver mitochondria of rats after varying periods of immobilization

Table 2: Activity of NADPH•H+- and NADH•H+-oxidoreductases of liver microsomes in rats (in umole/min/mg protein) after hypokinesia lasting 1 and 2 months

Table 3: Activity of catalases of the mitochondrial fractions (in ml O₂/min/mg protein) and SOD in liver mitochondria (in units/mg protein) and in hemolizates of erythrocytes (in units/mg Hb) in response to hypokinesia

EQUIPMENT AND INSTRUMENTATION: See Aviation Medicine M125;
Space Industrialization M128)

EXO BIOLOGY

(See also: Space Biology and Medicine M125; Space Industrialization M128)

PAPERS:

P858(18/88)* Telegina TA, Pavlovskaya TYe.

Melanin-melanoidin catalysts in the abiogenic synthesis of peptides.

Izvestiya Akademii Nauk SSSR: Ceriya Biologicheskaya.

1988(1): 112-116.

[25 references; 15 in English]

Authors' affiliation: A.N. Bakh Institute of Biochemistry, USSR Academy of Sciences, Moscow.

Exobiology, Abiogenic Synthesis

Peptides, Protein Precursors

Melanin-Melanoidin Catalysts, Ultraviolet Radiation

Abstract: Investigation of possible pathways of abiogenic synthesis of peptides, precursors of proteins, is significant in experimental study of prebiotic evolution. It is important to determine which conditions would permit the polycondensation of amino acids associated with overcoming the thermodynamic barrier to formation of peptide bonds. One possible factor conducive to this may be participation of heterogenic inorganic or particular organic catalysts. The catalysts themselves undoubtedly underwent evolution, changing from simple inorganic matrices, such as vulcanic minerals, to polyfunctional organic matrices (e.g., abiogenically-formed melanin and melanoidin matrices), which then would have become proteins. The authors conducted a study which demonstrated that ultraviolet irradiation ($\lambda = 25$ nm) of water solutions of acetaldehyde (2.5%) nitric salts of ammonia (1.5%), along with amino acids, peptides, pyruvic acid, and imidazole, induces the formation of dark pigments which are melanin-melanoid polymers. The authors hypothesize that the formation of peptides and other complex organic compounds in an aldehyde-ammonium salt system is associated with the presence of these polymer pigments, which may act as catalysts in the synthesis of these compounds and protect them from destruction by ultraviolet radiation. The melanin-like compounds formed have the property of strongly absorbing ultra-violet radiation. Monolayer technology was used to demonstrate that these pigments are capable of forming hydrophilic-hydrophobic oriented thin films at the phase boundary, with area of $0.5 \text{ m}^2/\text{mg}$. The isotherm contractility curves of these films are of the condensed type, and are not displaced by ultraviolet irradiation, indicating high photoresistance. The pigments readily form complexes with ions of transitional metals, another property important to their catalytic role.

The catalytic role of these pigments was studied in abiogenic synthesis of peptides from dilute solutions of amino acids. Peptide synthesis from a solution of alanine occurred with no radiation or in the presence of inorganic (silicagel) or organic (melanin-melanoidin) matrices under exposure to ultraviolet irradiation. It was demonstrated that formation of di-, tri-, tetra-, and possibly even peptides with higher molecular numbers was greater in the presence of ultraviolet irradiation when the organic

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catalyst was present. With both matrices, ultraviolet irradiation increased the output of peptides. Results with a control solution of alanine showed that when no matrices are present, ultraviolet radiation tends to destroy the small quantity of dipeptides that may be present in the equilibrium state of any amino acids or may be formed photochemically.

The authors conclude that their results show that polymer pigments of the melanin-melanoid type forming abiogenically in an acetaldehyde-ammonia salt system may perform functions of absorption, catalysis, and photoprotection in the abiogenic synthesis of peptides, during the period of prebiotic evolution.

GASTROINTESTINAL SYSTEM
(See also: Psychology M130)

PAPER:

P830(18/88) Smirnov KV, Goland-Ruvina LG, Medkova IL, Goncharova NP, Zhiznevskaya OV, Pechenikina RA, Dobrokvashina YeI.

Analysis of secretory processes in the gastrointestinal tract during long-term hypokinesia.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 363-364.

Gastrointestinal System, Hypersecretion; Metabolism; Enzymology

Humans

Hypokinesia, Head-Down Tilt, Long-Term

Abstract: Simulation experiments using animals and humans have shown that hypokinesia induces a number of changes in the functional state of the organs of the gastrointestinal tract. These changes involve the secretion, motility, and evacuation functions of the stomach, pancreas, small intestine, and the bile formation function of the liver. The functional state of the digestive system was studied in humans undergoing prolonged (120 days) hypokinesia with head-down tilt.

When the secretory function of the stomach was studied, a hypersecretory syndrome was identified. Increase in acidity was observed mainly in the cardiac portion of the stomach in the interdigestive period. Stimulated secretion changed less, suggesting that the functional capacities of the gastric glands are retained during hypokinesia with head-down tilt.

Secretion of the major pancreatic enzymes altered throughout the hypokinesia period. There was a decrease in amylase activity in duodenal contents during the initial period of hypokinesia, while during the latter period the concentration of this enzyme was relatively high. Blood amylase was elevated. Concentrations of enzymes responsible for hydrolysis of carbohydrates in the intestine decreased in duodenal juice and feces only toward the end of hypokinesia, at the same time that concentration of pancreatic amylase was high in duodenal juice. This finding suggests that hydrolysis of carbohydrates during hypokinesia changed little. Regulation of distribution of enzymes that hydrolyze carbohydrates throughout the gastrointestinal tract affected the nature of the glycemic curve. The portion of the glycemic curve which reflects hydrolysis and transport of carbohydrates in the gastrointestinal tract (initial 30 minutes - 1 hour after carbohydrate loading) was virtually unchanged during hypokinesia. Toward the end of the hypokinesia period, the curve was smoother, indicating some shifts in the endocrine portion of the gastric glands. Under conditions of hypokinesia, activity of the most important proteolytic enzyme, trypsin, decreased in duodenal contents and increased in blood.

Analysis of primary and secondary digestion of peptides under conditions of

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hypokinesia made it possible to establish that protein hydrolysis processes which involve pancreatic proteases, trypsin, and intestinal dipeptidases are attenuated in the small intestine. This could lead to a deficit of amino acids in body fluids and, in turn, to changes in protein metabolism. In addition, hydrolysis of fats, which involves pancreatic and intestinal lipase (monoglyceride lipase) decreased during hypokinesia. Investigation of the bile secreting function of the liver revealed an increase in the percentage concentration of bile acids conjugated with taurine and glycine [sic]. In addition, concentration of the lipoprotein complex of bile decreased. Decreases in the levels of bile acids conjugated with glycine [just said they increased??] suggests some degree of restructuring of the synthesis by hepatocytes. Decreased concentration of lipid complex of bile and decreased lipolytic activity of duodenal juice may worsen the conditions for lipid hydrolysis and absorption. The data cited indicate changes in hydrolytic processes in the gastrointestinal tract, occurring in response to hypokinesia with head-down tilt as a result of decreased activity of enzymes, which may not fully support effective hydrolysis of food. Increased concentration of hydrolytic enzymes (amylases, lipases, and trypsin) in blood may in turn induce changes in enzymatic homeostasis.

GENETICS

PAPER:

P850(18/88)* Mishurova Ye, Kropachova K (Czechoslovakia).

Changes in chromatin and nucleic acids in rat tissues after short-term space flight.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 78-80 ; 1988.

(16 references; 4 in English)

Genetics, Chromatin, Nucleic Acids, Lymphatic Organs

Rats, Males, Females, Sex Differences; Reproductive Biology, Pregnancy

Space Flight, COSMOS-1514, COSMOS-1667

Abstract: Pregnant female rats (n=5) were flown for 5 days on the COSMOS-1514 biosatellite (days 13-18 of pregnancy), and male rats (n=7) were flown for 7 days on COSMOS-1667. Both sets of animals were studied 4-12 hours after reentry. A ground-based simulation study reproduced all maintenance, launch, and landing conditions on board the satellite. Vivarium control animals were also studied. Decay of nuclear chromatin was determined by measuring concentrations of polydeoxyribonucleotides (PDRN) in chromatin fractions placed in saline solutions and centrifuged. Quantitative changes in RNA and DNA were assessed spectrophotometrically in alkaline and acid tissue hydrolysates.

No signs of chromatin decay were noted in either group of animals in the spleen or thymus. In male rats, level of nucleic acids in the lymphatic organs showed no statistically significant changes. Amount of nucleic acids, however, decreased by 1/3 in thymus of pregnant females and by 1/2 in their spleens. Pregnant females in the ground simulation condition showed some decrease in these parameters, but not to the extent of flight animals. No significant effects on DNA were detected in the leukocyte mass of blood, but blood RNA decreased by approximately 1/2 in females. The authors conclude that, unlike long-term flights, short-term biosatellite flights do not induce decay of nuclear chromatin in the spleens of either male or pregnant female rats. Decreased concentration of nucleic acid in lymphatic organs of pregnant females was more significant than in males, suggesting that additional physiological stress (pregnancy) under space flight conditions enhances changes in lymphatic organs.

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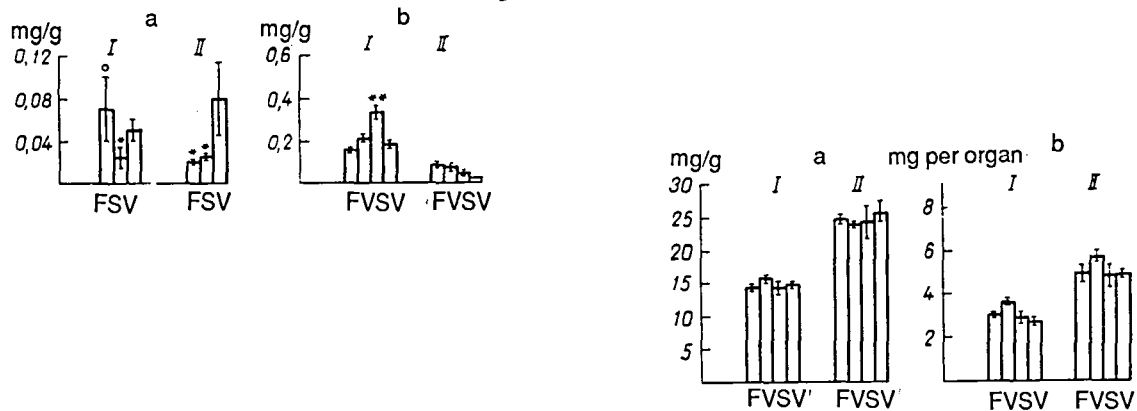


Figure 1: Concentration of PDRN (in mg per 1 g tissue) in the spleen and thymus of pregnant female rats after a 5-day space flight on COSMOS-1514 (a) and males after a 7-day flight on COSMOS-1667

I- spleen, II-thymus. Here and in figures 2-5, mean group values are cited. * and ** indicate differences from the vivarium control group with $p < 0.05$ and $p < 0.01$, respectively. o indicates difference from simulation control with $p < 0.05$.

Figure 2: Concentration (a; in mg per 1 g tissue) and total amount (b; in mg per organ) of RNA (I) and DNA (II) in thymus of males after 7-day space flight on COSMOS-1667

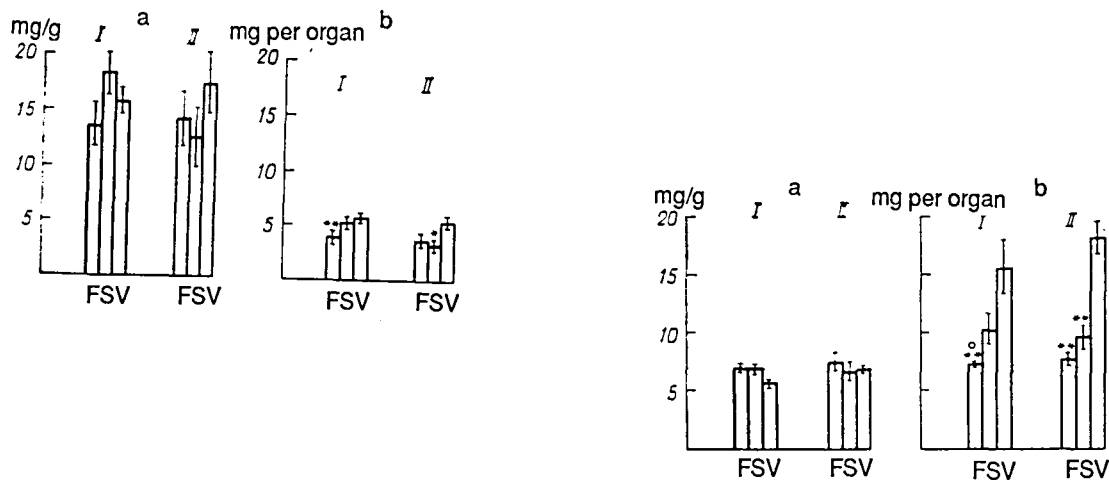


Figure 3: Concentration (a: in mg per 1 g tissue) and total amount (b; in mg per organ) of RNA (I) and DNA (II) in the thymus of pregnant rats after a 5-day space flight on COSMOS-1514

Figure 4 Concentration (a: in mg per 1 g tissue) and total amount (b; in mg per organ) of RNA (I) and DNA (II) in the spleen of pregnant rats after a 5-day space flight on COSMOS-1514

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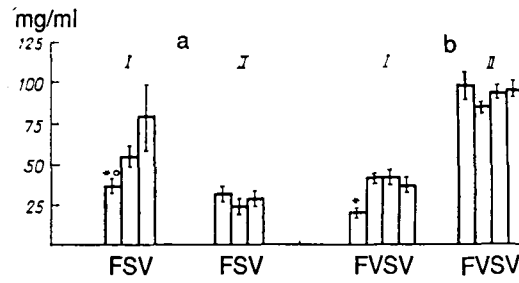


Figure 5: Concentration of RNA (I) and DNA (II: in ug/ml) in blood of pregnant female rats after a 5-day space flight on COSMOS-1514 (a) and male rats after a 7-day flight on COSMOS-1667 (b)

GRAVITATIONAL BIOLOGY
(See also: Special Feature P856)

MONOGRAPH:

M132(18/88) Gershuni GV. (editor)

Systemy organov chuvstv: Morfofunktsional'nyye aspekty evolyutsii [**Systems of sensory organs: Morphofunctional aspects of their evolution.**]

Leningrad: Nauka; 1988.

[189 pages]

Key Words: Gravitational Biology, Evolution, Sensory Physiology, Perception, Vision, Olfaction, Hearing, Chemoreception, Information Processing

Annotation: This collection contains review and experimental papers devoted to the morphofunctional aspects of the evolution of sensory systems. It considers issues involving the development, origin, and functional stability of receptors; problems of efferent regulation of the olfactory and auditory systems; molecular mechanisms underlying the transformation of intra- and intercellular signals; and systemic organization of vision and exterochemoreception. This collection is intended for specialists in evolutionary physiology of sensory systems, and also for biophysicists, neurologists, engineers and biologists who are interested in information processing systems.

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Abstract of chapter by Vinnikov: **The origin of gravity receptors.**

Based on data obtained in his laboratory and in the literature, the author develops the idea that the major structural and molecular mechanisms for sensory reception arose in one-celled flagellate eucaryotes, which had the capacity for modality-specific transformation of stimuli arising from certain forms of energy in the environment. When multicellular animals, regardless of phylum, began to develop sensory systems, certain genomes for transforming information (gravity receptors, eyes, organs of hearing, chemoreceptors) which were similar in structure and function arose again and again. In the author's opinion, during phylogensis sense organs arose by virtue of goal-directed, genetically reinforced behavior of animals toward physical stimulation. The author establishes that there are similar structural and functional links in the central nervous system between gravity receptors and visual organs in mollusks, arthropods, and vertebrates, resulting from the functioning of the muscles responsible for eye movement. 167 references; 15 figures.

GROUP DYNAMICS: See Personnel Selection M127; Psychology M131

HABITABILITY AND ENVIRONMENT EFFECTS

(See also: Aviation Medicine: BR13; Microbiology P821)

PAPERS:

P813(18/88) Markevich L (Warsaw).

Physiological changes evoked by long-term occupational exposure to vibration under industrial conditions.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages:94-95.

Habitability and Environment Effects, Physiological Effects

Humans, Pilots

Vibration, Occupational Exposure

Abstract: Vibration induces a number of physiological changes in the circulatory and nervous systems. The intensity and duration of exposure to vibration are the definitive factors. The author studied the changes observed in pilots after many years of exposure to vibration (2000-5000 and 200-1000 hours of flight). Effects were studied using impedance plethysmography of the arms and legs, polycardiography, and echocardiography. Visual response and biochemical parameters of blood were also assessed.

Fluctuations in volume parameters were insignificant. The smallest effect was observed in subjects with the greatest number of logged hours. These subjects also had a lower skin temperature measured in the fingertips.

Vibration sensitivity changed insignificantly. The subjects did not demonstrate disruption of cardiac rhythm or intracardiac conductivity; all poly- and echocardiographic parameters were within the norm. Angiographic parameters were virtually unaltered in the majority of individuals. Fluorescent angiography established the presence of widening of the precapillary vessels in the area of the central retina, retardation of filling with visual pigment, and increased intensity and duration of fluorescence of the fundus. Pilots with a greater number of flight hours showed an increased level of triglycerides in the blood.

All these changes show that the effect of vibration is not an occupational problem for pilots, although in some individuals it may cause a number of functional disorders.

P820(18/88) Drobyshev VI, Stepanova TP.

Response of neurocytes of the cerebral cortex to vibration.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 270-271.

Neurophysiology, Cerebral Cortex, Neurocytes

Rat

Habitability and Environment Effects, Vibration

Abstract: Morphological changes in the nervous system induced by vibration have been described by a number of researchers. However, few published works contain data about the reactions of the nervous system to vibration at frequencies close to resonant. It has been established that the resonant frequency is 75-80 Hz for the heads of rats, and 27-29 Hz for the abdominal cavity.

Research was performed on the response of neurocytes in the sensorimotor cortex of 36 Wistar rats, weighing 250-300 g, subjected to whole body vertical vibration with frequency of 30 Hz (groups 1 and 2) and 80 Hz (groups 3 and 4) for 1 hour. Rate of increase in vibration was 20 m/sec². The animals were either sacrificed immediately after the session (groups 1 and 3) or 6 hours after vibration (groups 2 and 4). There were 6 animals in each experimental group, and a control group contained 12 rats. The material was fixed in Carnoy fluid and then poured into paraffin and stained using Nissla's method. Neurocytes were subjected to karyometry. The data obtained were statistically tested using analysis of variance.

No significant changes were found in neurocytes of the sensorimotor cortex immediately after exposure to vibration with frequency of 30 Hz. The number of nerve cells with pale, large nuclei and narrow dark rings of cytoplasm increased; nucleoli were frequently displaced toward the periphery. Karyometry revealed a tendency for the volume of the nuclei to increase. Six hours after exposure, the proportion of altered nerve cells increased significantly ($p < 0.05$). Neurocyte nuclei were pale and swollen. Cells with central and peripheral chromatolysis, and fine-mesh peripheral vacuolization of the cytoplasm were observed. The volume of the neurocyte nuclei had increased compared to the control group ($p < 0.01$).

Changes were noted in the neurocytes of the sensorimotor cortex immediately after vibration at 80 Hz. Nuclei of a significant portion of the neurocytes were depleted of chromatophilic substance, and nucleoles were frequently displaced to the periphery. The nucleus was surrounded by a dark ring of cytoplasm, and lumps of chromatin were not always differentiated due to the brightness of the staining. The volume of neurocyte nuclei of this experimental group was greater than that of the control group ($p < 0.05$).

Six hours after vibration at this frequency, the number of altered neurocytes had increased significantly ($p < 0.01$). Some neurocytes had a swollen oval

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nucleus, and swollen branches. The cytoplasm displayed areas of central and peripheral chromatolysis and fine-mesh vacuolization. Large vacuoles were infrequent. A few shadow cells and pyknomorphic neurocytes were noted. The nuclei of the neurocytes were greater in volume than those of the control group ($p < 0.01$).

Thus, this research indicates that neurocytes in the sensorimotor cortex of rat brains are sensitive to vibration with oscillation at frequencies of 30 and 80 Hz. Changes in neurocytes can be noted immediately after exposure and have a tendency to increase after 6 hours. Changes are more severe after vibration at 80 Hz.

HEMATOLOGY

(See also: Adaptation P822, P857; Musculoskeletal System P826; Radiobiology P812; Space Biology and Medicine M125)

PAPERS:

P827(18/88)Naydina VP, Zharkovskaya YeYe, Ivanovna SM.

Investigation of the effects of hypokinesia and stress on the fatty acid composition of erythrocytes.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 353-354.

Hematology, Erythrocytes, Fatty Acids

Rats

Hypokinesia, Psychology, Immobilization Stress, Exercise

Abstract: The functional state of cell membranes depends, to a substantial extent, on the ratio between saturated and unsaturated fatty acids. The major portion of polyunsaturated fatty acids in lipids of many tissues is composed of arachidonic acid (C₂₀, four double bonds), which is a substrate for the formation of prostaglandins and products of lipid peroxidation. Activation of lipid peroxidation processes may be the reason for the lability of membrane structures (hemolysis) and inhibition of a series of membrane specific enzymes.

The authors studied the effects of hypokinesia, immobilization stress and physical exercise on the fatty acid composition of erythrocyte membranes of rats (males of the Wistar line, weighing 200 g) using gas chromatography. To limit motor activity the animals were placed in immobilization cages (control animals were maintained in ordinary vivarium cages). After 60 days of hypokinesia, certain animals (from both control and experimental groups) were compelled to perform strenuous physical exercise (swimming until exhausted), and also placed in a special device which totally immobilized the head and legs.

The greatest changes (in percentage) were noted in arachidonic acid concentration compared with that of other fatty acids. Immobilization stress significantly increased its concentration: from 13.6 (control) to 19.2% ($p < 0.01$). Hypokinesia, like stress, increased the level of arachidonic acid to 21.5% ($p < 0.001$) and decreased the concentration of saturated fatty acids: palmitic - from 33% (control) to 26.7% ($p < 0.001$) and stearic - from 20.4% (control) to 17.3% ($p < 0.01$).

When hypokinesia was combined with physical exercise and stress there were no additional changes in fatty acid composition (in comparison to hypokinesia alone).

Since increases in concentration of arachidonic acid, could potentially activate the process of lipid peroxidation and increase synthesis of prostaglandins, and/or mobilize calcium ions from bones, these results show

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the indisputable influence of long-term hypokinesia and immobilization stress on the functional state of erythrocyte membranes.

P845(18/88)* Sominskiy VN, Okun' KV, Anshelevich YuV.

Quantitative analysis of the interaction of propanol and erythrocyte membrane by measuring propanol's antihemolytic effect.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 67-69; 1988.

(21 references; 7 in English)

Hematology, Erythrocyte Membrane

Humans, Personnel Selection

Propanol, Antihemolytic Effect

Abstract: A total of 40 apparently healthy people, aged 22 to 48, were studied using pharmacoclinical methods for observing mediator-receptor interactions. This method involved constructing dissociation curves, in which the antihemolytic effect of propanol was plotted as a function of dosage. The interaction of propanol and erythrocyte membranes was evaluated according to changes in level of hypotonic hemolysis of erythrocytes for various doses of propanol. Samples of erythrocyte suspension in an isotonic phosphate buffer with a hematocrit number of 20% were incubated in the presence of the beta-adrenoblocker propanol at 37°C for 15 minutes in a vibrator. Extent of hemolysis was evaluated by measuring optical density of the resulting supernatant liquid. The dissociation constant and Hill coefficient (h) were computed.

At a propanol concentration of $2.3 \cdot 10^{-4}$ M, membrane response was not normally distributed and allowed identification of three groups of people: those with weak (1), moderate (2), and pronounced (3) responses. Groups did not differ in age. Group 3 constituted only 20% of the population. Hill coefficient and dissociation constants differed, with group 1 showing lowest values and group 2 highest for both parameters. The authors conclude that their results may be useful in occupational selection and prevention of adverse individual reactions to extreme factors.

Table 1: Effects of propanol on hypotonic hemolysis of erythrocytes

Table 2: Quantitative parameters of interaction between propanol and erythrocyte membranes of healthy individuals

P852(18/88)* Ivchenko VF, Stazhadze LL, Romanov AN, Omanidze DO.
Changes in bioenergetic parameters of erythrocytes in response to regional hypothermia under conditions of hypokinesia with head-down tilt(-8°).
 Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.
 22(2): 83-85; 1988.
 (14 references; none in English)

Hematology, Erythrocytes, Bioenergetic Parameters; Metabolism
 Humans, Males
 Hypokinesia With Head-Down Tilt, Regional Hypothermia

Abstract: A total of 48 apparently healthy men were studied before exposure to hypokinesia with head-down tilt and before, during, and on days 3, 7 and 14 after regional hypothermia to which they were subjected during the hypokinesia treatment. Twenty subjects were subjected to 5 hours of abdominal hypothermia, 9 to 5 hours of intragastric hypothermia and 19 to 3 hours of cerebral hypothermia. The first condition was achieved by applying cold to the abdominal region, the second by maintaining circulation of a cold liquid in a latex balloon inside the stomach, and the third by applying cold through a helmet. Body temperature dropped by 1-1.5°C during intragastric hypothermia, by 1°C in abdominal hypothermia, and by 0.1° in cerebral hypothermia. To study the activity of glycolytic processes in erythrocytes, experimenters studied fractions of the adenyl system (ATP, ADP, AMP) as indicators of erythrocyte bioenergetics. Plasma inorganic phosphorus (IP) was measured to produce information about changes in phosphate depo- and acid-base balance of the blood. Concentration of 2,3-diphosphoglycerate (2,3-DPG) (a participant in regulation of the oxygen transport function of the blood) was measured in venous blood.

Hypokinesia was associated with increased concentration of the major phosphorylated enzymes: ATP, ADP, AMP, 2,3-DPG, and IP, indicating increased glycolysis in erythrocytes as an adaptive response to the hypoxia associated with hypokinesia. Before hypokinesia, all types of hypothermia led to decreases in all the enzymes studied (decrease not significant for cerebral hypothermia). After abdominal and intragastric hypothermia, ATP increased significantly, AMP was absent, and 2,3-DPG and ADP decreased. IP increased only after intragastric hypothermia. Cerebral hypothermia led to changes in the same direction, but these were not statistically reliable. Increase in ATP, and decrease in ADP, AMP, and 2,3-DPG suggest activation of the direct path for glucose utilization. Decreased ADP and 2,3-DPG suggest decreased flow of metabolites in the pentosophosphate pathway and diphosphoglycerate shunt. The latter is confirmed by increase in concentration of IP, since this is the only point where IP can participate in glycolysis. Thus, despite the decrease in oxygen consumption under conditions of developing hypoxia, or possibly because of it, hypothermia stimulates glucose metabolism in erythrocytes on the Embden-Meyerhof pathway.

The authors conclude that hypothermia inhibits processes of glucose utilization along the pentosophosphate pathway and diphosphoglycerate shunt. This fosters recovery of conjugated oxidation attenuated by hypoxia. As a result, ATP accumulates. This may be important when hypothermia is terminated and during remaining exposure to hypokinesia. Restabilization of energy-producing processes during hypokinesia after exposure to hypothermia, suggests that metabolic processes undergo restructuring without functional

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stress. Perhaps this is the result of the accumulation of ATP, which in turn supports stability during normal erythrocyte metabolism.

HUMAN PERFORMANCE

(See also: Adaptation P824; Aviation Medicine P832, BRL3; Biological Rhythms P819; Personnel Selection M127; Psychology M131)

PAPERS:

P837(18/88)* Asyamolov BF, Voronin LI, Panchenko VS, Ulyatovsiy NV, Bondarenko RA, Kaliberdin AV, Elizarov SYu, Plokhova VG, Yarov AS.
Effectiveness of antigravity devices of the chamberless type after 7 days of hypokinesia with head-down tilt.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 37-40 ; 1988.

(11 references; 1 in English)

Human Performance, Operator Task, Acceleration Tolerance

Humans

Hypokinesia With Head-Down Tilt, Acceleration, Countermeasures, Antigravity Clothing

Abstract: The goal of this study was to provide information for developing means to protect operators from $+G_z$ acceleration. A total of 36 subjects, aged 20 to 31, participated in the study. All had been certified fit for centrifugation and hypokinesia with head-down tilt. Three conditions were run. In the first, 10 subjects spent 60 hours in hypokinesia with -6° head-down tilt during the night and -15° during the day. Before and after this treatment, subjects' endurance of $+3G_z$ was assessed for 15 minutes with and without antigravity device 1 (AGD-1). In the second condition, the effectiveness of AGD-1 was tested on 24 subjects before and after a 7-day period of hypokinesia with head-down tilt (-10°). The following acceleration schedule was used: 2.5- and 3.0-G for 5 minutes each, 3.5-, 4.0- and 4.5-G for 30 minutes each. In the third condition, endurance of 6 subjects was measured before and after a 7-day period of hypokinesia using the AGD-2 device and the same acceleration schedule as in condition 2. In all cases, acceleration increased at a rate of 0.1-G per second. AGD-1 consisted of closely fitting trousers made of stretch fabric with a high elasticity modulus which could maintain the perimeter and volume of the lower body under exposure to longitudinal G-load. AGD-2 was a shortened modification of AGD-1 reaching to the knees. Operator performance was evaluated in condition 3 during exposure to acceleration with a control task using a flight instrument providing information about flight parameters. Physiological parameters were assessed by an EKG with tetrapolar chest leads, photoplethysmography of the ear, and a myogram of the femur and abdominal muscles. Subjects were all trained to criterion on the control task before centrifugation.

In condition 1, 70% of the subjects endured $+3G_z$ for 15 minutes. All subjects tolerated this load while wearing AGD-1. After 60 hours of hypokinesia and head-down tilt, only 20% of subjects tolerated the given acceleration; the endurance of the remaining 80% decreased by 36.3%. The most common reason for terminating acceleration was visual gray-out, disruption of cardiac rhythm, and bradycardia. When AGD-1 was used all subjects tolerated acceleration for 15 minutes. In condition 2, all subjects tolerated acceleration before hypokinesia; after hypokinesia with head-down tilt, only 2 of the 24 subjects were able to do so. Mean decrease in maximum G-load endured was 1.75-G. When AGD-1 was used endurance

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decreased by only 0.13-G compared to baseline. Only 25% of the subjects were unable to tolerate +4.5-G. Physiological symptoms were less pronounced when AGD-1 was worn. In condition 3, it was found that AGD-2, developed because it provided more freedom of movement, was less effective in increasing acceleration tolerance than AGD-1. However, it did increase endurance considerably. Without the suit, 91.7% of the subjects could not endure +4.5-G; when AGD-2 was worn, only 33% of the subjects were unable to tolerate this acceleration. Differences between AGD-1 and AGD-2 were only noted for G-loads greater than 3.0. In condition 3, operator performance parameters during acceleration after hypokinesia with head-down tilt were significantly improved when AGD-2 was worn.

The authors conclude that even 60 hours of hypokinesia with head-down tilt decreased G-load tolerance, and this tolerance further decreased after 7-days of the treatment. Associated with decreased tolerance is poorer performance on a control task during acceleration. Use of antigravity suits improves not only physiological endurance of acceleration, but also operator performance.

Table: Decrease in endurance of acceleration after a 7-day period of hypokinesia with head-down tilt, without antigravity devices and with AGD-1 and AGD-2

Figure: The effects of 7 days of hypokinesia with head-down tilt on endurance of longitudinal G-loads, with and without an antigravity device

IMMUNOLOGY

(See also: Adaptation P857; Psychology M130; Radiobiology P812;
Space Biology and Medicine M125)

PAPERS:

P843(18/88)* Kirillova YeN, Muksinova KN, Skykovskaya TL.

The effect of long term continuous irradiation on humoral immunity parameters in mice.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 62-65; 1988.

(14 references; 8 in English)

Immunology, Humoral Immunity

Mice

Radiobiology, Gamma Radiation, Long-Term Irradiation

Abstract: A total of 1050 mice were irradiated daily with a ^{137}Cs gamma emitter in a dose of 12 cGy per day up to a total dosage of 5 Gy. Exposure sessions lasted 22 hrs/day. During irradiation and then 3 and 10 months after its termination, concentrations of cells in bone marrow, thymus, spleen, and lymph nodes were measured. The number of CFUs (colony-forming units) in the bone and spleen was studied by exocolonization, and antibody formation in response to sheep erythrocytes was also measured. Cooperation between B-lymphocytes and T-helpers in humoral response to thymus-dependent antigens and T-suppressor activity was also measured. To evaluate B-lymphocytes or T-helper function, bone marrow or thymus cells from an experimental animal were injected into a lethally irradiated recipient along with intact thymocytes or myelokaryocytes. Concentration of antibody-forming cells was measured on day 8 after the injections. The capacity of B- and T-lymphocyte precursors to restore the function of a population of B-lymphocytes and T-helpers was investigated with a similar method, using suspended marrow or thymus cells obtained from animals which had received a lethal dose of radiation 7 days (for bone marrow samples) or 20-25 days (for thymus samples) after bone marrow transplants of $3 \cdot 10^7$ cells per mouse from experimental or control groups. An untreated control group was used for all analyses. Between 10 and 28 mice were used in each control or experimental group.

Daily continuous irradiation as described above led to decrease in the number of cells in the central as well as peripheral lymphoid organs, which reached 15-30% of baseline by day 4 of treatment (total dose 50 cGy) and continued at that level until its termination. Only the lymphatics showed significantly more depletion (50% of the norm). After irradiation, myelokaryocytes were 80-90% of the norm in months 3 and 6 after termination and fully normalized by month 10. Normalization occurred in the thymus in month 10. The spleen showed an elevated number of cells 6 months post treatment, but at month 10 cell content was 25% below baseline. Hypoplasia was more resistant in the lymph nodes, with concentration leveling off at 56% control level. Concentration of CFUs decreased by half in bone marrow when mice received a radiation dosage of 50 cGy and remained 20-25% of the norm until the end of the treatment. Dynamics were similar in the spleen. Three months after irradiation, CFUs concentration in both organs had reached 80% of the norm. Full recovery did not occur in marrow after either 6 or 10 months. In the spleen, concentration of CFUs was above normal

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at 6 months and 87% normal at 10 months. Active precursors of B-lymphocytes displayed a tendency to decrease after a total radiation dose of 2 Gy. By the end of the treatment, parameters relating to the functioning of these cells exceeded control levels, evidently due to increased proliferation of stem cells and committed lymphocyte precursors. After treatment, B-lymphocyte precursors showed a tendency to decrease. Function of T-helper precursors decreased by 30% only after irradiation. Hypoplasia of lymphoid tissue and decrease in the number and function of lymphocyte precursors led to a gradual decrease in production of antibodies. Thus, at a total dosage of 2-3 Gy, concentration of antibodies decreased to 65% in the spleen, and after 4-5 Gy to 25-35%. Three months after treatment termination this parameter had normalized, but it decreased again subsequently (to 76% control). This effect is considered to be the result of a decrease in the functional capacity of B- and T-lymphocytes to 46-60% of norm due to their decreased numbers, depression of cooperative capability and probably also of their migration and reciprocity properties. In spite of the restoration of B-lymphocyte function when the animals had received the maximum dose, increased production of antibodies was not noted during that period, evidently due to decrease in the cooperative function of T-helpers by 25%. Increased activity of B-lymphocytes noted 10 months after treatment termination was due to increase of the repopulating capacity of splenocytes. The suppressing capacity of T-lymphocytes of the spleen was reduced by 20% at treatment termination, but increased to 70% above control 10 months after irradiation.

The authors conclude that long-duration continuous radiation caused changes in all immune cells and functions important in response to thymus-dependent antigens. Greatest effect occurred in polypotent lymphocyte precursors leading to hypoplasia of lymphoid organs. This in turn led to depression of antibody production. Committed precursors showed less damage. Tendency for antibody production to be depressed during the remote period after irradiation was due to incomplete recovery of cells in the peripheral lymphoid organs, the pool of polypotent lymphocyte precursors in bone marrow, and the functioning of committed precursors and B-lymphocytes and T-helpers. Decreased antibody production led to increased suppressor activity of T-cells in the spleen.

Figure 1: Number of cells in bone marrow, thymus, spleen, and lymph nodes of irradiated mice

Figure 2: Changes in CFUs and functions of lymphocyte precursors in irradiated mice

Figure 3: Production of antibodies and lymphocyte functions in irradiated mice

P849(18/88)* Durnova GN, Borotnikova YeV.

Histological study of lymphoid organs of rats after a 7-day space flight on the "COSMOS-1667" biosatellite.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 75-77; 1988.

(11 references; 3 in English)

Immunology, Thymus, Spleen

Rats

Space Flight, COSMOS-1667

Abstract: The experimenters studied the thymus and spleen of 7 male rats after a 7-day flight on the COSMOS-1667 biosatellite and 7 rats in a ground-based control condition simulating all space flight factors except weightlessness. Two untreated control groups were used. Subjects were sacrificed 4-8 hours after reentry. Lymphoid organs were weighed, fixed, poured into paraffin, and cross sections obtained and stained. Morphometric analyses were also conducted. Areas of lymphoid follicles and their light centers were measured in the spleen, and areas of cortical and medullary substance in the thymus.

Weights of thymus and spleen were reduced by 12 and 18%, respectively in flight animals compared to the untreated control group. No effect was found for spleen and thymus weights in the synchronous group. Half of the subjects in the flight group showed a slight or moderate number of macrophages with phagocytary residuals of lymphocyte nuclei in the thymus. The other half showed no destructive changes. Initial signs of hypoplasia of the thymus were found in flight rats, and were most pronounced in rats showing greatest weight loss in the thymus. The flight group rats showed smaller ratios between areas of cortical and medullary substances than did control rats, suggesting hypoplasia of the lymphoid tissue of the thymus. The spleens of flight animals showed some decrease in the size of lymphoid follicles and their light centers. Some neutrophilic infiltration was seen in the red pulp of the spleen. No effects were found in the lymphoid organs of the ground simulation group.

The authors state that both acute and chronic effects can be seen in the lymphoid tissue of their flight subjects. The acute changes (e.g., lymphocyte destruction in the thymus, and neutrophilic infiltration in the spleen) are attributed to gravitational stress of reentry. However, effects like decreased thymus mass and hypoplasia of the white pulp of the spleen develop no earlier than 10 hours after stress and thus cannot be attributed to reentry. Signs of gravitational stress were more pronounced in rats returning to Earth after longer flights.

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Table 1: Change in weight of lymphoid organs in rats after 7-day space flight

Group	Thymus		Spleen	
	absolute weight, mg	relative weight, mg per 1 g body weight	absolute weight, mg	relative weight, mg per 1 g body weight
Space flight	193.4	0.58*	523.6	1.57*
Control (1)	235.1	0.71	591.9	1.77
Ground simulation	198.8	0.57	632.9	1.81
Control (2)	189.1	0.54	614.4	1.76

* Here and in table 2, differs significantly from appropriate control

EDITOR'S NOTE: Significance of results on thymus may be attributable to outlying values for the first control group.

Table 2: Results of morphometric studies of the lymphoid organs of rats after flight on COSMOS-1667 biosatellite

Group	Thymus	Spleen	
	1	2	3
Space flight	2.62*	1.32	26.6
Control (1)	3.20	1.74	34.7
Ground simulation	2.92	1.50	20.0
Control (2)	2.72	1.46	35.9

1 - ratio of area of cortical substance to area of medullary substance

2 - area of lymphoid follicles, mm²

3 - area of light centers of lymphoid follicles, um²

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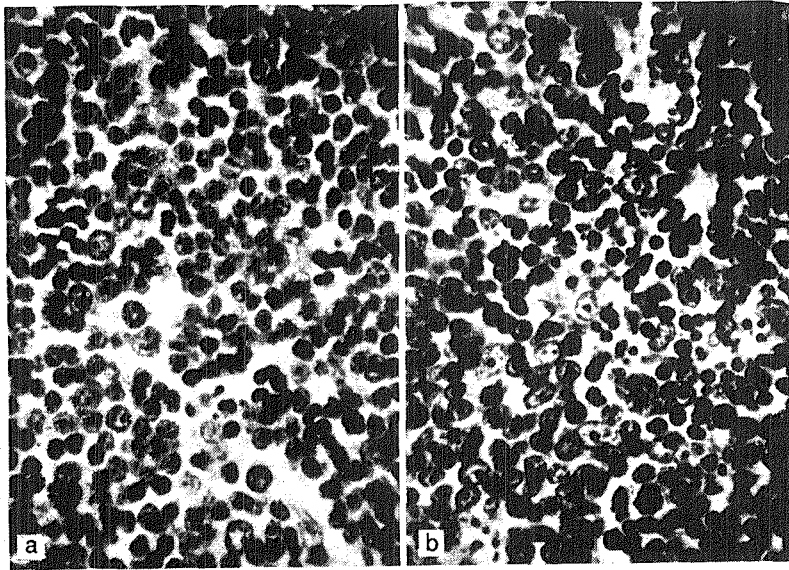


Figure 1: Thymus of rats after short-term and long-term space flights
 a - macrophages with phagocytary nuclear detritus in the cortical substance of the thymus after 7- day space flight; b - mass destruction of lymphocytes and accumulation of nuclear detritus in cortical substance after long-term space flight.

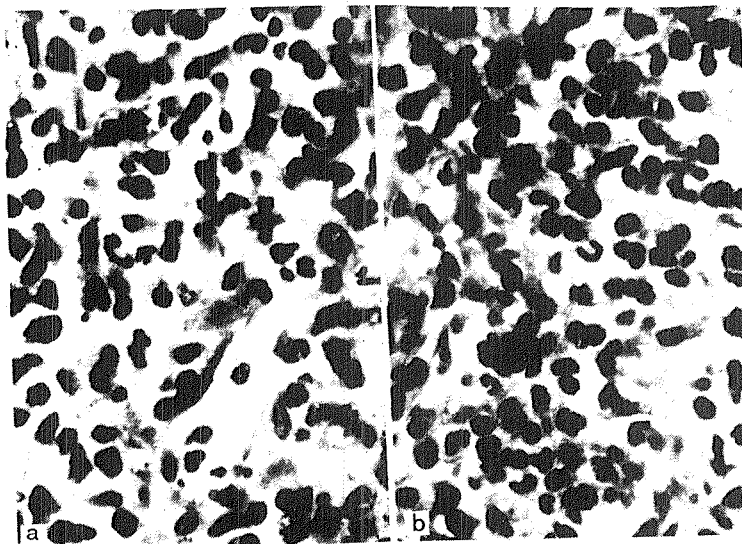


Figure 2: Spleen of rats after short-term and long-term space flights
 a - neutrophilic granulocytes in the red pulp of the spleen after 7-day space flight; b - intensive diffusion and infiltration of neutrophils of the red pulp of the spleen after long-term space flight.

LIFE SUPPORT SYSTEMS

(See also: Body Fluids P854; Microbiology P821;
Space Biology and Medicine M125)

PAPERS:

P841(18/88)* Shikina MI, Vinogradova LA, Kolesina NB.

Microflora in drinking water reclaimed from condensate of atmospheric moisture of a hermetically sealed living space.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 53-55 ; 1988.

(6 references; none in English)

Life Support System, Reclaimed Drinking Water

Microbiology, Microflora

Hermetically Sealed Environment

Abstract: The goal of this study was to investigate dynamics of changes in quantity and species of microorganisms obtained from condensate of atmospheric moisture and water produced by a reclamation system in a hermetically sealed human living environment. Microorganisms of the groups of intestinal bacilli, enterococci, fecal streptococci, pathogenic enterobacteria, and gram negative bacteria were studied in samples with regard to epidemiological danger and drinking water safety. In order to study certain metabolic processes characteristic of the vital activity of microbial cells and their virulent properties, the authors used traditional bacteriological methods to determine rate of redox reactions (using the parameters of total dehydrogenase activity), enzyme nucleic metabolism (DNA activity), hemolytic properties, and capacity to produce plasmocoagulase, lecitinase and fibrinolysine.

Analysis showed that the highest parameter of microbial concentration in atmospheric condensate entering the water reclamation system was recorded during the first 7-10 days of the system's functioning (10^5 - 10^6). Subsequently, the quantity of microorganisms in condensate samples stabilized at 10^4 - 10^2 [sic. 10^5 ?] microbe bodies per 1 ml. Certain condensate samples were virtually sterile after being processed by the system. The quantity of microorganisms in the reclaimed water was 10^4 - 10^5 bodies per 1 ml, which was within safe values. In samples of condensate, Staphylococcus aureus and Staphylococcus epidermitis constituted 1 - 80% of all bacteria. Acinetobacter lwolffi+parapertussis from 50 to 99%, Micrococcus luteus - 10 to 60%, Aeromonas hydrophilla from 10 to 15%, Alcalineges faecalis from 5 to 20% and Citrobacter fruendii from 0 to 10%. After processing, the condensate fully met state standards for drinking water. The most common bacteria found were Alcaligenes faecalis. After 7 months of storage of the reclaimed water, the number of microbe bodies increased from 20 to 2700. Neither the condensate nor reclaimed water contained typical intestinal bacilli (E. coli), while concentration of fecal streptococci an indicator of microorganisms in common drinking water was depressed or absent. Although bacteria found showed none of the characteristics of virulent species, certain lines showed increased enzyme, DNA and lecitinase activity, production of plasmocoagulase and hemolytic characteristics. This was especially true in Acinetobacter-Morazella.

The authors conclude that during the functioning of a water reclamation

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system in a hermetically sealed environment occupied by humans, microflora obtained from atmospheric condensate and reclaimed water were situation-specific in their composition and retained their viability with high stability.

MAN-MACHINE SYSTEMS: See Aviation Medicine BRL3; Psychology M131;
Space Biology and Medicine M125

MATHEMATICAL MODELING: Musculoskeletal System M126;
Space Biology and Medicine M125

METABOLISM

(See also: Adaptation P822, P857; Enzymology P807;
Gastrointestinal System P830; Hematology P852;
Musculoskeletal System P810, P840; Space Biology and Medicine M125)

PAPERS:

P825(18/88) Artamanova NP, Zakharova TS, Morukov BV, Arzamazov GS, Semenov VYu.

Dynamics of EKG parameters and blood electrolytes in apparently healthy humans during long-term hypokinesia.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 331-332.

Metabolism, Body Fluids, Electrolyte Metabolism, Cardiovascular and
Respiratory Systems, EKG Parameters
Humans, Males
Hypokinesia, Head-Down Tilt, Long-Term

Abstract: Changes in electrolyte metabolism occur in space flight and during hypokinesia. This affects the bioelectric activity of the myocardium and is one of the causes of changes in EKG parameters. The interrelationship between changes in concentrations of potassium, sodium, calcium (total and ionized), and magnesium in blood serum and EKG parameters have been clinically studied in patients with diseases of the visceral organs. The question of compensating for changes in electrolyte metabolism and EKG parameters during exposure to space flight factors has received little study.

The goal of the research being described is identification of the interrelationship between changes in the concentration of electrolytes in blood serum and dynamics of EKG parameters in healthy males subjected to long-term hypokinesia with head-down tilt. Six apparently healthy males, aged 30-45 participated; the study involved a 120-day period of hypokinesia with head-down tilt (-4.5°). Electrocardiograms were recorded (using the 12 standard leads and three bipolar chest leads on the "Mingograph-82" apparatus) during a baseline period and on days 1, 7, and 28 of hypokinesia; every subsequent 2 weeks until the treatment terminated; and on days 1, 14, and 25 of the recovery period. Blood was taken from the ulnar vein 30 minutes after each electrocardiogram was recorded. Concentrations of potassium and sodium were determined using flame photometry on the IL-743 apparatus. Total calcium was measured titrimetrically on the Corning-940 analyzer, ionized calcium was estimated with ion-selective electrodes using the Nova-2 analyzer, while magnesium was measured with the Saturn atom-

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absorption spectrometer. The SM-4 computer was used to perform correlational analyses on the data obtained.

During the baseline period EKG parameters remained within normal limits for all subjects. During hypokinesia with head-down tilt, beginning in week 2, observations showed diffuse decreases, flattening and some broadening of T waves, and sometimes transitory deformation, with an accompanying tendency toward longer electric systole (QT), a phenomena typical of mild hypokalemia. This process stabilized somewhat in the second half of the treatment period, when there was a tendency for concentration of potassium to decrease and concentration of total and ionized calcium and magnesium to increase. Concentrations of these electrolytes returned to baseline level by day 25 of the baseline period.

Mathematical analysis established that there were correlations between EKG changes in the T_{II} , T_{V2} , T_{V5} waves and changes in electrolyte

concentrations. The highest correlations with EKG parameters were noted with magnesium: $r(Mg-AT_{II}) = -0.90$; $r(Mg-AT_{V5}) = -0.85$; $r(Mg-AT_{V2}) = -0.80$.

Correlations between potassium and calcium and EKG parameters were also moderately high: $r(K-AT_{II})=0.75$; $r(K - AT_{V5})=-0.81$; $r(Ca - AT_{II})= -0.72$.

Thus, changes in EKG parameters, characteristic of mild hypokalemia, began at the end of the first month of long-term exposure to hypokinesia with head-down tilt. At the same time blood levels of potassium tended to decrease and levels of magnesium and ionized calcium tended to increase. The associations observed between dynamics of EKG parameters and shifts in the ion composition of blood attest to the metabolic nature of changes in bioelectric activity of the myocardium, thus facilitating identification of means to compensate for these changes.

P828(18/88) Popova IA, Nosova YeG. Vetrova YeG, Dedenyanyan NV, Drozdova TYe, Zaytseva LB.

Proteins and products of protein metabolism under conditions of long-term hypokinesia.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 356-357.

Metabolism, Protein, Creatinine, Urea, Uric Acid

Humans

Hypokinesia With Head-Down Tilt, Long-Term

[See abstract P838 (Metabolism) this Digest issue.]

Abstract: Concentrations of total protein, creatinine, urea, and uric acid were measured in the blood serum of 9 men undergoing a 120-day period of hypokinesia with head-down tilt. In addition the ratios of protein fractions were measured by electrophoresis of the protein on acetate cellulose, followed by densitometry. Enzymatic activity of serum proteins was determined using enzyme spectrophotometric methods and a standard set of reagents.

As a consequence of the decrease in motor activity and energy expenditure, the 120-day hypokinesia period was marked by a decrease in the enzymatic activity of serum proteins associated with processes of energy formation. In particular, activity of oxidizing enzymes of the Krebs cycle, malate and isocitrate dehydrogenases decreased, as did creatinine phosphokinase and its muscular isoform. At the same time, there was virtually no change in activity of anabolic metabolism enzymes -- aldolases and alanine- and aspartate aminotransferases. The activity of bone enzymes -- alkaline and acid phosphatase -- increased toward the end of the second month of hypokinesia and remained at a high level throughout the remainder of the treatment. Resumption of normal activity after hypokinesia was accompanied by activation of enzymes of oxidative metabolism, creatine phosphatases, and alanine aminotransferases.

Toward the end of month 1 of bedrest, there was a reliable decrease in the concentration of total protein and albumins in blood, persisting throughout the remainder of the treatment and the first month of the recovery period. The most probable reasons for this are disruption of serum protein synthesis in the liver as a result of its decreased functional activity during hypokinesia and decrease in protein assimilability under these conditions.

During the 120-day period of hypokinesia, while statistically reliable changes in the concentration of total globulins did not occur, there was a clear change in their fractional composition: phase changes in the level of alpha₁-globulins, increased concentration of beta-globulins throughout the entire hypokinesia period, followed by normalization in the initial days of the recovery period; and decreased level of alpha₂- and gamma-globulin fractions, persisting during the first month of recovery. These shifts were

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most likely caused by changes in the functional state of the liver during long-term hypokinesia. It may be hypothesized that changes in the fractional composition of globulins, in turn, affect the state of the blood transport systems, as well as immunological resistance.

The decreased level of serum protein found in this experiment is consistent with data that other experimenters obtained from these same subjects and attests to an increase in the pool of free amino acids as a result of increased rate of proteolysis processes in muscle tissue.

During the hypokinesia period, concentrations of creatinine and urea increased in blood, while renal excretion of these protein metabolism products did not change significantly. Concentrations of uric acid in blood throughout the 120-day treatment were virtually unchanged, while renal excretion increased and reached a maximum during months 2-3 of hypokinesia.

The data obtained attest to adaptive changes in the processes of tissue metabolism that occur when motor activity is restricted, as well as to the significant role of protein metabolism in biochemical adaptation to long-term exposure to hypokinesia with head-down tilt.

P829(18/88) Prilipko LV.

Adaptation and normalization of calicum metabolism under conditions simulating weightlessness.

In: Gizenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 360-361.

Metabolism, Calcium; Adaptation; Musculoskeletal System; Endocrinology, Pituitary-Adrenal System

Humans

Hypokinesia, Horizontal, Head-Down Tilt; Nutrition, Vitamin D

Abstract: Some effects of weightlessness have been studied on the ground using horizontal and head-down hypokinesia. Prolonged limitation of motor activity, hypokinesia, and certain working conditions are known to induce internal changes in calcium metabolism and bone tissue.

Experiments were conducted on male rats maintained in individual immobilization cages for 40 days. Experimental horizontal and head-down tilt (-30°) hypokinesia led to hypocalcemia in rats. As is well known, Vitamin D plays an important role in regulating calcium metabolism. Previous research has shown that Vitamin D metabolism is disrupted in hypokinesia. Administration of the minimum required dose of functionally active metabolites of vitamin D₃ -- 1,25(OH)₂ D₃ (1,25-dioxycalciferol), 24,25 (OH)₂ D₃ (24,25-dioxycalciferol); and their combination -- had a normalizing effect on the parameters of calcium metabolism and the state of bone tissue, such as concentration of total calcium, inorganic phosphate, activity of alkaline phosphatase in blood plasma, concentration of calcium, phosphorous, and oxypropoline in the diaphyses and epiphyses of femur bones.

The results of experimental work show that active metabolites of Vitamin D₃ are effective in preventing and correcting disruption of calcium metabolism and bone changes in hypokinesia.

From the standpoint of the mechanisms underlying their effects, Vitamin D₃ metabolites can be thought of as a kind of hormone. Hormonal effects may influence reactivity of endocrine glands and the overall hormonal status of the body, while the combined effects of different hormones may differ from the known effects of the same hormones individually.

When changes occur in the internal and external environment, the functional state of the pituitary-adrenal system is highly significant, since this system plays an important role in formation of assimilative reactions, development of adaptation and resistance, and maintenance of work capacity.

The authors conducted a study of the pituitary-adrenal system during horizontal hypokinesia and hypokinesia with head-down tilt (-30°) lasting 40 days, with administration of minimum necessary dose of active metabolites of Vitamin D₃ and their combination. Concentrations of ACTH, catecholamines, and corticosterone were measured in blood plasma and tissues.

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The experiment showed that the normal dynamics of these hormones was not disrupted when metabolites of Vitamin D₃ were introduced to normalize and prevent calcium metabolism and bone changes in hypokinesia.

P831(18/88)* Potapov PP, Fedorov IV.

Metabolic aspects of readaptation after hypokinesia (results of animal experimentation).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 4-10; 1988.

(47 references; 8 in English)

Metabolism, Protein, Collagen Synthesis; Adaptation, Readaptation
Animals
Hypokinesia

Abstract: This paper attempts to review and draw general conclusions from published material concerning changes in animal metabolism during the readaptation period after hypokinesia varying in duration. Total weight loss associated with hypokinesia has been shown to normalize in 1 week after 15 days of restricted movement; 30 days of hypokinesia requires 3-4 weeks to normalize; while a 90 day period requires 2 months. Muscle mass of the hind legs normalized in 1-2 weeks after 7, 14, and 28 days of tail suspension. Experimental data indicates that rate of protein synthesis increases in skeletal muscles, even after brief periods of hypokinesia. Collagen synthesis rate evidently does not change and recovery depends on the increase of functionally active proteins and muscle mass. The majority of authors have found that hypokinesia of from 7 to 90 days decreases muscle glycogen in animals. This parameter fluctuates widely for a long period after treatment, attesting to disrupted balance between synthesis and utilization of polysaccharides in muscles. After 19- and 90-day periods of hypokinesia, triacylglycerol accumulated in the skeletal muscles of rats, normalizing after 30 and 90 days, respectively. After 7 days of hypokinesia, activity of hexokinase was elevated on days 7-10 of recovery, while glucose-6-phosphate dehydrogenase was elevated on day 5. Activity of both these enzymes had been depressed during the treatment itself. After 90 days of hypokinesia, activity of hexokinase and glucose-6-phosphate dehydrogenase, which had been depressed during treatment, gradually normalized over a 1-month period, while lactate dehydrogenase remained elevated for 2 weeks. After a 4-week hypokinesia treatment, activity of citrate synthetase increased in the muscles of the hind legs, and citrate concentration increased in the same muscles after 60 days of restricted movement. Work capacity of muscles remained depressed after hypokinesia, even when collagen and muscle mass had virtually normalized. Static endurance was particularly low.

Effects of hypokinesia on recovery levels of glycogen in the liver were similar in nature to effects on the muscles. After 1- and 2-weeks of limited motion, liver glycogen was elevated, but then dropped below baseline, normalizing after 30 days. After a 30-day treatment, liver glycogen was 10 times higher on day 7 of recovery than it had been during the experiment and 2.5 times higher than the norm. These changes persisted after 2 months of readaptation. After 3 months of hypokinesia, liver polysaccharides were normal on day 15 of recovery and depressed on day 30. In another study, glycogen increased after a 90-day period of hypokinesia, starting on day 5 and normalizing after 1.5 months.

Blood sugar generally showed a pattern of changes similar to that of liver glycogen after hypokinesia. The glycemic reaction to adrenalin was more pronounced than the norm, while hyperglycemia after glucose loading was

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lower than the norm. Activity of phosphoenolpyruvate carbokinase remained elevated after 7 and 90 days of hypokinesia during the early recovery period. After 2 months of treatment, concentration of glycogen amino acids was depressed in blood plasma and tissues. Transaminase activity increased in liver tissue for 10 days after a 30-day hypokinesia period. Inclusion of amino acids in protein of the liver, kidneys, heart, spleen, and small intestine decreased during a 2-week period of limited movement, persisting for 6 days into the recovery period. After 7 days of hypokinesia, activity of lactate dehydrogenase (days 1-5) and hexokinase (days 5-10) were elevated. Severe hypokinesia lasting 7 and 15 days led to decreased triacylglycerine and increased cholesterol in the liver, which normalized after 1 week. After a 30-day treatment, both parameters remained very low for the first week of recovery. Triacylglycerol remained low for 60 days, while cholesterol increased after 1 month. After a 3-month treatment, these parameters dropped. On day 30 of recovery, liver cholesterol was elevated, but subsequently normalized.

After 1 and 2 weeks of hypokinesia, serum triacylglycerol, cholesterol, and phospholipids were elevated until day 15 of readaptation. On day 7 after a 30-day treatment, marked increases in triacylglycerol and hypercholesteremia were noted; subsequently, parameters normalized on day 15, but cholesterol was again elevated on days 21 and 60. Phospholipids were normal for 3 weeks and then showed a tendency to decrease. After 3 months of limited activity, hypercholesterolemia persisted for 90 days, while triacylglycerols fluctuated sharply. Free fatty acids in serum were elevated for a long period after 7, 15, and 90 days of hypokinesia; however, this parameter was depressed during recovery after 30 and 60 days of treatment. After 2 months of hypokinesia, lipolysis and hormonal stimulation of this process were elevated, but after 3 months of treatment the same parameters were depressed. After rabbits had sustained 2 weeks of limited motion, cholesterol and lipoproteins were elevated on day 14 of recovery and normalized by day 35. When the lipoprotein spectrum of blood serum was analyzed using disk electrophoresis during the recovery period after 15- and 30-day hypokinesia, it was observed that after the shorter treatment alpha-lipoproteins remained elevated for 2 weeks. After the longer period, arterogenic lipoproteins continued to be elevated on days 1-7 and 24-29. The data obtained show that changes in blood and liver lipids are highly variable after hypokinesia and depend strongly on the duration of the preceding treatment period. One common effect is increased lipid transport during the recovery period. It was also found that during readaptation after 7, 15, and 90 days of hypokinesia, activity of glucoso-6-phosphate dehydrogenase and NADP-dependent cytoplasmatic isocitrate dehydrogenase in the liver and fatty tissue increases, suggesting increased rate of lipid synthesis.

The authors argue that during the initial period of recovery after hypokinesia, there is a pronounced anabolic response which serves to restore the functionally active muscle proteins and the substrates of energy (catabolic) metabolism. At the same time, synthesis of lipids -- and especially carbohydrates -- outweigh their utilization, suggesting that during the early recovery period use of amino acids increases to cover energy required for glycogenesis and liposynthesis, limiting protein synthesis.

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This in turn suggests that amino acids should be increased in the diets of people in analogous situations. The authors emphasize that the changes observed after recovery from hypokinesia do not take the form of smooth, gradual normalization of disrupted functions. When no special measures are introduced, complete normalization requires a period at least equal to the duration of preceding hypokinesia. In some cases, metabolic changes during recovery are more severe or dangerous than those during treatment itself. "Overcorrection" can be observed in a number of parameters, which the authors attribute to pathology of the regulatory mechanisms. Further research should involve more than one or two hypokinesia periods and post-treatment observation period should at least equal treatment duration.

P838(18/88)* Popova IA, Morukov BV, Arzamov GS, Vetrova YeG, Delen'yan NV, Drozdova TYe, Zaytseva LB, Rustam'yan IA.

Characteristics of metabolism in response to 120 days of hypokinesia with head-down tilt.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 40-45; 1988.

(14 references; 3 in English)

[See Abstract P828 (Metabolism), this Digest issue.]

Metabolism, Mineral Balance; Enzymology

Humans, Males

Hypokinesia With Head-Down Tilt, Long-Term, Nutrition

Abstract: This study used as subjects 9 men aged 25-44, who underwent a 120-day period of hypokinesia with head-down tilt (-50°). The subjects were given a controlled diet containing 42.4-55.6 mequiv Ca and 21.4-28.6 mequiv Mg and other essential minerals. Mineral balance was noted during a 20-day baseline period, throughout hypokinesia, and during a 7-day recovery period. Urine and feces were collected daily. Blood was taken from the ulnar vein in the morning before breakfast twice in the baseline period; on days 8, 28, 49, 72, 92, 112, and 120 of hypokinesia, and on days 2 and 7 of recovery. Concentration of Na and K in urine and blood serum or plasma was determined using flame photometry. Ca was measured titrimetrically and ionized Ca activity was measured using an ion-selective electrode. Mg was measured with an atom-absorption spectrophotometric flame. Protein and products of protein-nitrogen metabolism were measured using a Technicon automated analyzer. Serum proteins were fractionated through electrophoresis on acetate cellulose. Enzyme activity in blood was measured by standard methods.

Blood Na was virtually unchanged throughout hypokinesia, while Mg showed a tendency to increase during the treatment period. Serum K was depressed on days 8, 72, and 120 of hypokinesia and during the recovery period. Starting on day 28 of treatment, total serum calcium was significantly higher than during baseline. During recovery this parameter did not differ from baseline. Activity of ionized Ca fractions in blood serum was elevated by 16-24% throughout the treatment period and remained above baseline on day 7 of recovery. These measurements are consistent with space flight data.

When Ca balance was computed using data on renal and intestinal excretion, many individual differences were noted during the treatment. Ca loss ranged from 9.64 to 35.04 g and averaged 20.14 g during hypokinesia. Analysis showed that, in general, negative calcium balance results from increased excretion, as well as decreased absorption in the gastrointestinal tract; some individuals may show evidence of only one of these mechanisms. All subjects but one developed a negative K balance during hypokinesia. Pattern of Mg loss generally corresponded to loss of Ca but was less pronounced.

During hypokinesia, while water consumption was unchanged, increased diuresis led to decreased body hydration. On day 1 of recovery, water consumption increased and daily diuresis decreased, suggesting a negative fluid balance during treatment. Weight loss, uncorrelated with fluid loss, averaged 1.8 kg for the group, and was mainly attributable to loss of muscle mass.

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During treatment concentration of total protein and albumin in blood serum decreased reliably and toward the end of the period equalled 68.4 g/l and 48.5 g/l (compared to 82.3 and 60.3 g/l during baseline). Although no statistical changes were found in concentration of total globulins, their fractional composition did alter, with fluctuations in α_1 -globulins, increases in beta-globulins followed by normalization, and decreased gamma-globulins through day 7 of recovery. Blood concentrations of the major nitrogenous products of protein metabolism and creatinine increased substantially during hypokinesia and had not normalized by day 7 of recovery. In spite of increased urea and creatinine, renal excretion remained normal throughout the study. Blood uric acid remained the same, while its renal excretion increased during treatment and recovery. These results are interpreted as indicating that altered protein metabolism resulted from hypohydration and loss of muscle mass. Results of studies of serum enzyme activity, an important indicator of tissue metabolism, are presented in the table below. Changes in enzyme activity, which are consistent with space flight results, are attributed to altered characteristics of anabolic and catabolic metabolism. The authors conclude that measurement of enzyme activity in blood serum is a useful indicator of the status of metabolism in the body.

Table 1: Concentration of electrolytes and activity of ionized Ca in blood

Table 2: Ratio of renal and intestinal excretion of Ca in response to a 120-day period of hypokinesia with head-down tilt

Table 3: Ca and Mg during a 120-day period of hypokinesia with head-down tilt

Figure 1: Changes in concentration of total protein, albumins and fractional composition of globulins in blood serum

Figure 2: Changes in concentration of nitrogenous metabolites in blood and their renal excretion

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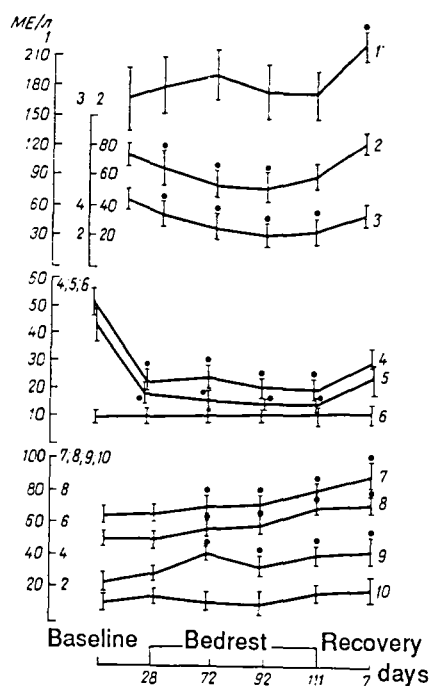


Figure 3: Change in enzyme activity in blood serum

1 - lactate dehydrogenase; 2 - malate dehydrogenase; 3 - isocitrate dehydrogenase; 4 - total creatinine phosphokinase; 5 - MM-isoenzyme of creatinine phosphokinase; 6 - aspartate aminotransferase; 7 - alkaline phosphatase, total activity; 8 - alkaline phosphatase, bone isoenzyme; 9 - acid phosphatase; 10 - alkaline phosphatase, liver isoenzyme.

P851(18/88)* Vorob'yev VYe, Stazhadze LL, Kal'yanova VN, Repenkova LG, Ivchenko VF, Vetrova YeG, Lenskiy WV, Kovachevich IV.

Tissue metabolism in humans in response to hyperoxygenation during hypokinesia with head-down tilt.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 80-83; 1988.

(8 references; 4 in English)

Metabolism, Tissue; Enzymology

Humans, Males

Hypokinesia With Head-Down Tilt, Hyperoxygenation

Abstract: A total of 16 apparently healthy males, aged 24 to 45, were studied during a 14-day period of hypokinesia with head-down tilt (-80°). Subjects were further exposed to a 45-minute period of isobaric hyperoxygenation created by artificial ventilation of the lungs. Artificial ventilation was created under general anaesthesia using sodium oxibutyrates and seduxen (Diazepam) and total muscle relaxation. Hyperoxygenation was induced before the beginning of hypokinesia and on day 12. Oxygenation of arterial blood was maintained at a mean of 320 mm Hg in both instances. Gas composition and acid-balance were measured in arterial and venous blood and electrocardiography was performed. Concentrations of inorganic phosphate, lactate, and pyruvate were measured in venous blood and excess lactate computed. In addition, activity of the following enzymes was measured: NAD-dependent malate dehydrogenase (MDH), NADP-dependent isocitrate dehydrogenase (IDH), and lactate dehydrogenase (LDH).

In the baseline period, lactate was decreased by hyperoxia by 47%, while pyruvate increased by 71%, and their ratio decreased by 69%. There was no lactate surplus. With hyperoxia during hypokinesia, the ratio of lactate : pyruvate increased by 42% (lactate decreased by 21.5% and pyruvate by 33%) compared to the value when subjects breathed air. Lactate surplus increased. In this case, lactate surplus cannot be interpreted as caused by tissue hypoxia. Cardiovascular responses to hyperoxia (decreased minute volume, increased peripheral vascular resistance, and decreased heart rate) did not differ during baseline and hypokinesia, indicating that lactate surplus was not due to inadequate tissue perfusion. An alternative explanation for increased lactate : pyruvate ratio in response to hyperoxia during hypokinesia is that pathways for transporting reduction equivalents across the mitochondrial membrane are altered. Evidence supporting this idea includes the fact that MDH and IDH activity are higher during air breathing in hypokinesia, than under baseline conditions, but do not increase in response to hyperoxia in the former case, as they do in the latter. In hypokinesia, but not baseline conditions, lactate dehydrogenase activity increases in response to hyperoxygenation. The authors conclude that the factors determining the effects of hyperoxia on the metabolic processes in tissues under conditions of hypokinesia with head-down tilt are dissociation of respiration and phosphorylation, increased utilization of the pentose pathway and possibly use of pentose metabolism products in glycolysis.

Table 1: Changes in tissue metabolism parameters in blood of subjects exposed to oxygen

Table 2: Enzyme activity in blood serum and lipid concentration in plasma

MICROBIOLOGY

(See also: Adaptation P857; Life Support Systems P841;
Space Biology and Medicine M125)

PAPERS:

P821(18/88) Deshevaya YeA, Novikova A.

Characteristics of the formation of microflora in hermetically sealed living quarters with altered composition of the atmosphere.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 230.

Life Support Systems, Hermetically Sealed Environments

Microbiology, Microflora, Mold, Pathogenic

Habitability and Environment Effects, Atmosphere, Acetic Acid

Abstract: An important issue relating to the use of hermetically sealed living quarters is averting disease in human inhabitants. Despite an extensive set of disinfectant measures applied when the hermetically sealed living space is prepared for use, mold has consistently been found in the living environment. Such microorganisms may induce various toxic-allergic states in the operators. The epidemiological significance of mold under these conditions is particularly great since the likelihood of their penetrating the human body is increased by the limited size of the living area and its lack of ventilation.

Research was performed to study the formation of microflora in a hermetically-sealed living space with altered gaseous composition of the air. The concentration of vapors of acetic acid was altered from 5 to 25 mg/m³. It has been established that increasing concentration of acetic acid changes the quantitative and species composition of microflora in the air. Thus, mold of the family Penicillium, which are often found in the atmosphere of a hermetically sealed living space, were not recorded with acetic acid concentration of 25 mg/m³. The mold spores most resistant to the effects of acetic acid vapors belonged to the species Aspergillus flavus and Aspergillus fumigatus.

The next stage in the study was to determine the pathogenic properties of molds found on the surfaces and in the atmosphere of a hermetically sealed living space with increased concentration of acetic acid. Among the microflora identified were some lines of mold which are considered conditionally pathogenic. The extent of their pathogenicity was studied by infecting the abdominal cavities of laboratory animals with a suspension of mold spores. Pathogenic properties were found in representatives of the species Aspergillus flavus and Aspergillus fumigatus, which were also the most resistant to the altered gaseous composition of the atmosphere. The data obtained are preliminary, but extremely important in their epidemiological implications, since the presence of pathogenic molds in the atmosphere may adversely affect the hygienic status of the hermetically-sealed living space.

MUSCULOSKELETAL SYSTEM

(See also: Adaptation P857; Metabolism P829; Radiobiology P853;
Special Feature P856)

PAPERS:

P810(18/88) Volozhin AI, Stupakov GP, Druzhinina RA, Rogacheva IV, Polyakov AN.

Pharmacological prevention of bone changes in hypokinesia and hypodynamia.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 31-32.

Musculoskeletal System, Osteoporosis; Metabolism, Phosphorus, Calcium,
Protein

Rats, Rabbits

Hypokinesia, Hypodynamia, Immobilization, Amputation, Pharmacological
Countermeasures, Calcitonin, Retabolil

Abstract: Osteoporosis has been shown to develop under space flight conditions in the epiphysis and metaphysis of long tubular bones in experimental animals (tortoises, rats). These consequences are a result of adaptation by the musculoskeletal system to conditions of limited motor activity (hypokinesia) and lack of gravitational loading on the skeleton (hypodynamia). Return to normal gravity requires readaptation, which may continue for a prolonged period. For this reason it is important to investigate the possibility of slowing skeletal adaptation to weightlessness through use of drugs that regulate phosphorus, calcium, and protein metabolism to correct bone metabolism.

The current experimental investigation was performed in two stages. In stage 1, long-term hypokinesia was modelled in rats and rabbits immobilized in small cages with the support function of the legs retained. Administration of calcitonin under these conditions led to decreased excretion of Ca and partial normalization of the major parameters of mineral and protein metabolism in bone tissue, but not normalization of skeletal growth. Calcitonin can be successfully combined with anabolic drugs, e.g., somatotrophic hormone; however, the latter have only short-term effects.

A better model for studying pathogenesis of bone changes in weightlessness is the elimination of the support function of the legs by unilateral disarticulation of the lower leg. Such conditions induce changes in the mineral component and restructuring of bone tissue and its mechanical properties, similar to those occurring during actual space flight. For this reason, stage 2 of the experiment involved use of this model in 20- and 40-day experiments on rats to study the possible prophylactic effect of retabolil [19-Nor-testosterone-17 beta decanoate] and calcitonin on osteoporosis engendered by amputation of the lower third of the lower leg. Calcitonin (a drug obtained from the thyroid of pigs) was subcutaneously injected in an amount of 2 units MRC daily subcutaneously and retabolil

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injected intramuscularly in an amount of 0.2 ml once in 10 days. Results of micro-X-ray, morphological and biomechanical investigation of bone tissue supported the conclusion that these drugs inhibit development of osteoporosis.

It was established that calcitonin and retabolil increased the density and mineral saturation of the head and distal epiphysis of the femur bone over both observation periods. The use of retabolil alone or in combination with calcitonin had no effect on the mean amount of mineralization of the microstructure of bone tissue epiphysis. Among the conditions studied, the most pronounced prophylactic effect on the development of regional osteoporosis resulted from the combination of the two drugs. Thus, there is basis for concluding that it is possible to counteract disorders of bone metabolism in hypodynamia with drugs. Such treatment may slow adaptation of the skeletal system to weightlessness and thus decrease the adverse effects of readaptation to Earth's gravity.

P815(18/88) Triftanidi LA.

The effect of hypokinesia on bone tissue.

In: Gizenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 141-142.

Musculoskeletal System, Histology, Bone Tissue, Restructuring, Osteoporosis
Rats

Hypokinesia, Immobilization

Abstract: Restructuring of bone tissue in physiological and pathological conditions leads to alteration of bone structure during adaptation to changing metabolic and mechanical conditions. Thus, the loss of bone mass is observed under conditions of actual and simulated weightlessness and various forms of hypokinesia, including those associated with certain contemporary occupations. At present, the problem of immobilization osteoporosis is becoming increasingly significant both from a theoretical and a practical point of view. The processes of restructuring bone tissue in response to restricted motor activity have not been studied adequately, and there is little existing data in the literature on this question.

The authors studied the process of restructuring of long tubular bones (femur and tibia) in adult white rats 7, 14, 21, and 30 days after hypokinesia (in individual immobilization cages) with optical and electron microscopes. In the electron microscope studies, decalcified bone tissue from the proximal metaphysis of the tibia was used.

Histological examination showed a gradual thinning of the trabeculae of the metaphysis and significant shortening of the primary spongiosa, up to the point of atrophy. In some cases, the metaphysis trabeculae displayed restructuring of bone tissue accompanied by signs of hemorrhage in sinusoid blood vessels; some of the vessels showed symptoms of sludge. In the widened intertrabecular space, bone marrow edema was associated with trabecular atrophy. The cortical layer retained its compact structure, but structures in the internal surface were ???. Electron microscopy on days 7-14 revealed areas of resorption (appearing more osmophilic than the remaining bone matrix) in the boundary zone of bone structure at a depth of an order of 0.5-1.5 μ m and extent of up to 80-100 μ m. In the destruction zone, disorganization of hydroxyapatite crystals was noted. Areas of resorption were either directly adjacent to or at some distance from the osteoclasts. Active forms of osteoclasts in direct contact with altered trabecular surface were observed in the cambial zone with enchondral ossification. On day 21, in addition to the changes described above, there were areas of resorption near the trabecular boundaries in the form of notches of mineralized bone substance, between which were collagenous fibrills 30-60 nm in diameter. Osteoclast cells were not found in contact with such zones of destruction.

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Osteoblasts were observed in the mineralized zones of the osteoid with cytoplasm containing an insignificant quantity of thickened canals of endoplasmic reticulum, ribosomes and 1 or 2 mitochondria. The nucleus was oval and eccentrically located. Between the osteoblast plasmalemma and the layer of partially mineralized osteoid was a space filled with a finely dispersed amorphous substance of low electrical density. Such cells can be considered to be osteoid osteocytes. In the deeper layers of the bone trabeculae, along with normal osteocytes, there were osteocytes with cytoplasm containing calcium crystals. Such osteocytes were also seen in the cytoplasm of some osteoblasts and osteoclasts, directly adjacent to the trabeculae. On day 30 calcium crystals were also seen in bone marrow tissue.

Thus, decrease in the mass of primary spongiosa and thinning of trabeculae in the metaphysis zone of the long tubular bones may be explained by disruption of the restructuring of bone tissue in hypokinesia. Along with the processes of resorption (lacunary and smooth), retardation of the process of bone formation was also observed (presence of osteoid osteocytes in the zone of osteoid mineralization, partial death of osteoblasts) and dystrophic and degenerative processes increased as hypokinesia was maintained for longer periods.

P826 (18/88) Gol'dovskaya MD, Shvets VN.

Study of the association between changes in bone mass and number of hemopoietic stem cells.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 338-339.

Musculoskeletal System, Bone Mass; Hematology, Stem Cells

Mice

Osteoporosis, Disuse, Amputation; Osteopetrosis, EHDA

Abstract: It is well known that there is a close association between bone and myeloid tissue. Thus, one might conclude that the decrease in bone mass and depression of erythropoiesis observed in weightlessness are interrelated processes. One hypothesis proposes that stromal mechanocytes of bone marrow play a definite role in regulating differentiation and proliferation of hemopoietic stem cells, so that the association between the skeletal and hemopoietic systems occurs at the level of precursor hemopoietic cells. To verify this hypothesis, the authors performed experiments in which they studied the number of hemopoietic stem cells in mice when there was an increase or a decrease in the mass of trabecular bone tissue in the metaphysis of the tibia bone. Stem cells were studied by cloning them on the spleens of lethally irradiated mice. Bone mass was decreased by cutting the tendon of the bone joint, resulting in local disuse osteoporosis in the tibia. After this procedure, spongiosa volume decreased by 55-61%. Bone mass was increased by injecting the mice with EHDA (ethane-1-hydroxy-1,1-diphosphonic acid) in a dose of 20 mg/kg. This dosage creates a situation similar to osteopetrosis. In this experiment a daily subcutaneous injection of EHDA for 7 days increased the volume of spongiosa by a factor of 2-3 compared to control.

The results of the research showed that the quantity of macrocolonies on the spleen, reflecting the number of hemopoietic stem cells remained at control level when the spongiosa became more or less dense. No correlation was found between the number of precursor cells of hemopoiesis and changes in the mass of bone tissue. This may be explained by the capacity of stem hemopoietic cells for constant repopulation in other organs associated with hemo- and lymphopoiesis, and thus the absence of any strong association with bone tissue. However, this does not exclude the possibility of a functional association between depressed erythropoiesis and loss of bone tissue in weightlessness, since cells of the erythrocyte series, as distinguished from stem cells, are always present in marrow and retain a constant association with bone.

MUSCULOSKELETAL SYSTEM

P855(18/88)* Gol'dovskaya MD, Shvets VN.

Relationships between changes in bone mass and number of hemopoietic stem cells.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 91-93; 1988.

(14 references; 8 in English)

[Note: Essentially same as above experiment]

Musculoskeletal System, Spongiosa

Mice

Disuse Osteoporosis, Amputation; Osteosclerosis, EHDA

Abstract: To induce disuse osteoporosis, the knee joint tendon was severed in one leg of F_1 mice. After 10 days the mice were sacrificed and tibia removed, fixed, decalcified, poured into paraffin, and cross sections prepared and stained. Controls were the corresponding leg bones of experimental mice and the bones of untreated mice. Morphometric analyses were performed to evaluate development of osteoporosis in the spongiosa of the proximal metaphysis of the bones. Bone marrow was extracted from the treated and untreated control bones and injected into recipient mice which had received a lethal dose of irradiation 4-5 or 24 hours previously. On day 8 after treatment, recipients were sacrificed, their spleens isolated, and the number of cell colonies counted. A total of 60 donor mice (40 treated and 20 untreated) and 230 recipients were used. In addition, ethane-1-hydroxy-1,1-diphosphonic acid (EHDA) was injected subcutaneously in 15 mice for 7 days in a dose of 20 mg/kg. This substance increases bone volume by inhibiting resorption. A control group was injected with distilled water, while a third group was untreated. One day after the last injection, the mice were sacrificed and bone marrow was extracted from their tibia bones and injected in previously lethally irradiated recipients. After 8 days, recipients' spleens were isolated and the number of colonies counted. Donors bones were examined for signs of osteosclerosis. The possibility of EHDA directly affecting recipients' spleens was investigated. A standard ocular matrix was used to investigate volume of trabeculae.

Histomorphometric studies showed that severing the knee joint tendon led to loss of bone mass (spongiosa volume) by approximately a factor of 2. In spite of this, the colony-forming capacity of treated bones was no different than that of controls. Introduction of EHDA in intact donors led to increase in spongiosa volume by more than a factor of 2. In the metaphysis, colony forming erythrocytes increased by a factor of 1.5. However, injection of EHDA in irradiated recipients had no greater affect than injection of distilled water. Distilled water additionally led to a reduction of bone mass. There was no correlation between change in bone mass and number of colony-forming erythrocytes.

Table 1: Relationship between changes in bone mass and number of colony-forming erythrocytes in osteoporosis

Table 2: Relationship between changes in bone mass and number of colony-forming erythrocytes in osteosclerosis

Table 3: Colony formation in the spleen in response to EHDA

P840 (18/88)* Shvets VN, Pankova AS, Kabitskaya OYe.

Osteotropic effect of xydiphon administered subcutaneously to rats during immobilization.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 49-53; 1988.

(14 references; 6 in English)

Musculoskeletal System, Osteotropic Effects; Metabolism, Calcium

Rats

Immobilization, Pharmacological Countermeasures, Xydiphon (Ksidifon)

Abstract: The drug xydiphon (hydroxyethylidene biphosphonic acid) is a phosphorous-containing compound with metal ions, used in medicine to treat disturbances of calcium metabolism. This work investigated the effect on osteoporosis of various doses of this substance administered subcutaneously to rats exposed to hypokinesia. A total of 80 Wistar rats divided into 8 groups were used in the experiment. Group treatments are summarized in the table below. Hypokinesia (how it was induced not specified) lasted 60 days. After the experiment terminated, animals were sacrificed and their tibia, iliac, spine and breastbones isolated, fixed, decalcified, sectioned and stained. An ocular grid and/or ocular microscope were used to determine volume of spongy bone tissue in the proximal section of the metaphysis of the tibia, throughout the spine, breastbone, and iliac. The volume of spongy bone tissue in the area of the three former types of bone, the width of the ephiphyseal growth layer and its individual zones in the tibia were also measured. Number of osteoblasts and osteoclasts in a field of view was counted in the area of the primary spongiosa of the tibia.

Spongy bone decreased in all groups subjected to hypokinesia in all bones studied, particularly in the tibia. This was also true of growth layer width in general and of all the individual zones. Subcutaneous administration of 1 and 5 mg/kg xydiphon tended to increase spongy bone mass in the tibia and significantly increased it in the spine, compared to the group undergoing hypokinesia with no drugs. These doses had no effect on the growth layer. Animals not exposed to hypokinesia but receiving xydiphon showed no changes in bone, with the exception of an increase in spongy tissue of the tibia in the 5 mg/kg group. Hypokinesia led to a decrease in spongy bone in the primary spongiosa of all bones, particularly in the tibia. Daily administration of 1 and 5 mg/kg xydiphon led to statistically significant increases in spongy bone mass in the tibia, spine, and breastbone. In the latter two bones, this parameter was equivalent to control values. Nonimmobilized animals receiving xydiphon showed similar effects. These results differ from those obtained previously with oral administration of the drug [See Digest Issue 6 P234 (Musculoskeletal System)], which is attributed to failure of xydiphon to be absorbed in significant doses while in the intestine.

Results of counting osteoblasts and osteoclasts shows that xydiphon produces an imbalance in these numbers. While hypokinesia decreases the numbers of both types of cells proportionately, xydiphon increases the number of osteoclasts relative to the condition with no drugs, and further decreases numbers of osteoblasts. These results appear paradoxical, but may not be so when it is remembered that xydiphon has been shown to decrease osteoclast activity while increasing their numbers. It may even be conjectured that this drug further increases osteoblast activity while decreasing their

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numbers. The authors conclude that whatever the mechanism of xydiphon's effects, it is a promising treatment of disuse osteoporosis.

Table: Effects of xydiphon on number of bone cells in the tibia

Treatment	Number of cells in field of view		Number of cells per 1% bone tissue	
	osteoblasts	osteoclasts	osteoblasts	osteoclasts
1. Control	127	18.0	2.5	0.36
2. Hypokinesia	51.4*	9.2*	1.87*	0.33
3. Hypokinesia + 1 mg/kg xydiphon	30.0*	12.6*	0.87*	0.37
4. Hypokinesia + 5 mg/kg xydiphon	19.4*	11.4*	0.5*	0.3
5. Hypokinesia + placebo	48.0*	8.5*	1.71*	0.3
6. Control + 1 mg/kg xydiphon	100	17.0	2.1	0.35
7. Control + 5 mg/kg	51.0*	19.0	0.88*	0.32
8. Control + placebo	104	17.4	2.2	0.36

* difference from group 1 statistically significant.

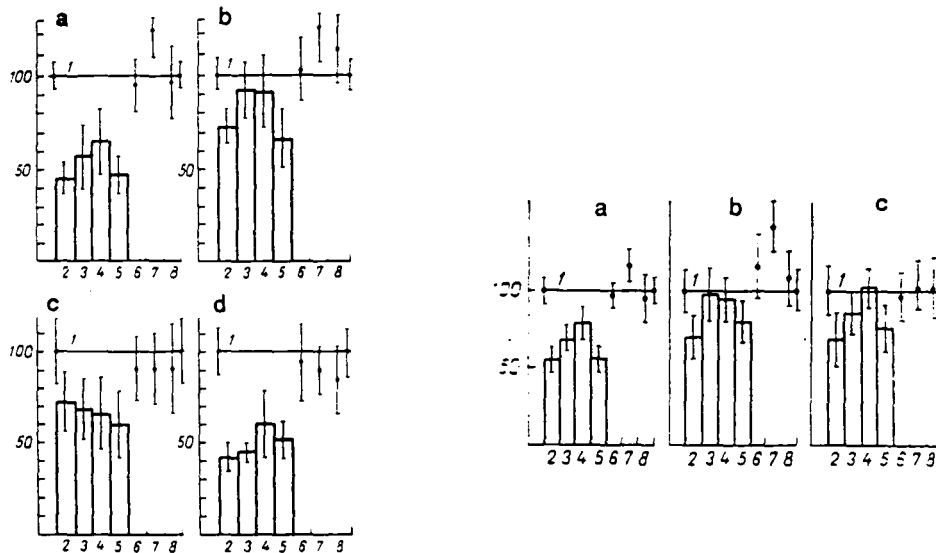


Figure 1: Histogram of changes in density of spongy bone, in the tibia (a), spine (b), breastbone (c), and iliac (d). Here and in Figure 2: abscissa - group number, ordinate - density of bone (in % relative to group 1). Vertical lines indicate confidence interval for $p = 0.05$.

Figure 2: Histogram of changes in density of spongy bone in the area of the primary spongiosa of the tibia (a), spine (b) and breastbone (c).

MONOGRAPH:

ML26(18/88) Stupakov GP, Kozlovskiy AP, Kazeykin VS.
 Biomekhanika pozvonochnika pri udarnykh peregruzka v praktike aviatsionnykh i kozmicheskikh poletov. Problemy kosmicheskoy biologii. Tom 56.
 [Biomechanics of the spine in response to impact G-load in aircraft and space flight. Problems of space biology. Volume 56.]
 Moscow: Nauka; 1987.
 [240 pages; 70 tables; 92 figures; 236 references]

KEY WORDS: Musculoskeletal System, Spine, Impact G-Load, Space Flight, Biomechanics, Weightlessness, Osteoporosis, Mathematical Modeling

Annotation: This monograph is devoted to one of the most critical issues in aviation and space medicine -- study of the general principles associated with human tolerance of impact G-load. A biomechanical approach is used to estimate safe levels of external mechanical forces acting on the human skeletal system, particularly the spine. The authors present a detailed discussion of the biomechanical, physiological, and pathophysiological changes occurring in response to longitudinal, transverse, and lateral G-load.

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NEUROPHYSIOLOGY

(See also: Adaptation P857; Cytology P823;
Habitability and Environment Effects P820; Personnel Selection M127;
Psychology M130; Special Feature P856)

PAPERS:

P814(18/88) Tkachev VV, Relushkina GD.

Study of parameters of ultraslow activity of the human brain during emotional stress from a space medicine perspective.

In: Gizenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 138.

Neurophysiology, Ultraslow Activity, Brain
Humans, Reaction Types
Psychology, Stress

Abstract: Neurophysiological measurement of ultraslow brain activity convincingly demonstrates that quasi-stable differences in potential (omega-potential) from the surface of the head are an objective reflection of functional state and adaptive capacity. Recording discrete omega-potentials from the surface of the head has been used successfully in sports medicine for medical monitoring and determining adaptation to extreme levels of exertion. Practitioners of space medicine could easily adapt the current technology for recording omega potentials to evaluate the state of an individual and assess adaptation to extreme conditions (including diagnosis of fatigue and premorbid states).

Omega potential dynamics were studied in 9 men, aged 24-38, during performance of tests involving stressful mental performance under time pressure. These tests were conducted lying down and involved sequential solution of two arithmetic problems (mental multiplication of two-digit numbers in 2 minutes) and one linguistic task (construction of meaningful sentences out of words beginning with a certain letter in 2 minutes). The amplitude of the omega potential was measured once per minute with glass, nonpolarized silver chloride electrodes.

Analysis of the results of recording the omega-potential showed that under conditions of physical rest, stressful intellectual activity induced at least two types of reactions. In the first type of reaction, characteristic of someone capable of adapting to stress, there is a great deal of change in the omega potential; increase in the amplitude of the omega potential during the period of functional stress and decrease after solution. Fluctuations of the omega potential are strictly synchronized with changes in the performance situation and state of the central nervous system. The second type of omega-potential reaction was characterized by monotony, and dampened fluctuations of the amplitude of the potential throughout the test. This occurred because emotional stress was still present between problem-solving attempts.

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The omega-potential reaction types identified, reflecting functional state of the central nervous system, may be used in medical monitoring during space flight. The more complex issue of intermediate types of omega-potential reactions to stress factors needs further study.

P817(18/88) Yasnetsov VV, Shashkov VS.

Participation of the endogenous opioid system in the genesis of vestibular and autonomic disturbances in motion sickness.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 159-160.

Neurophysiology, Motion Sickness, Vestibular System, Endogenous Opioid Peptides

Humans, Individual Differences, Endurance; Cats

Acceleration, Pharmacological Countermeasures, Naloxon, Scopolamine

Abstract: The pathogenesis of motion sickness is complex and requires further study. In the authors' view, the role that various neurochemical substrates of the brain, particularly, the endogenous opioid system, play in the development of motion sickness is of substantial scientific and possibly practical significance.

Motion sickness was induced in 19 apparently healthy males through cumulative effects of Coriolis and precessional acceleration (Bryanov test). Effects of naloxon (Nalorphine Hydrochloride) have provided indirect evidence that endogenous morphinelike substances participated in the genesis of motion sickness. The effectiveness of naloxon was evaluated with respect to the effects of a placebo and scopolamine. Naloxon had both a prophylactic and a therapeutic effect, demonstrating that endogenous opioids did contribute to the genesis of vestibular and autonomic disturbances in motion sickness. Thus, when the drug was taken before acceleration, the endurance period increased significantly ($p < 0.01$) by 1.7 ± 0.6 min (55+21%). The therapeutic effect corresponded to the prophylactic one, endurance time increased by 2.7 ± 1.0 minutes (60+24%). Scopolamine was less effective than naloxon -- endurance time increased by only $29 \pm 7\%$.

As direct proof of the participation of endogenous opioids in the genesis of motion sickness, the authors analyzed subjects' blood plasma for beta-endorphine. The plasma concentration of the peptide ($p < 0.05$) increased immediately after acceleration, from 8.3 ± 2.9 to 52.4 ± 16.9 fmole/ml. One hour after acceleration the level of beta-endorphins was 11.3 ± 3.0 , after 3 hours -- 3.3 ± 0.7 , and after 5 hours -- 3.0 ± 1.4 fmole/ml. It was found that naloxon did not affect the initial (immediately after acceleration) surge of peptides (concentration increased from 5.3 ± 0.5 to 53.8 ± 16.8 fmole/ml; $p < 0.02$), but decreased its concentration ($p < 0.05$) to 2.4 ± 1.2 fmole/ml 1 hour after the treatment. This accords with subjects' reports of improved well-being after the acceleration test when naloxon was administered. It was also reported that individuals more susceptible to motion sickness and subjects who vomitted showed especially high levels of beta-endorphins immediately after acceleration, while relatively tolerant individuals showed lower levels. All these facts provide a basis for considering beta-endorphins to be one of the biochemical "markers" of vestibular stress. Since naloxon has no effect on the initial "surge" of beta-endorphins, but increases endurance time to the acceleration test, we may conclude that

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there is an important central component in the protective effects of drugs against motion sickness.

Other proofs of the participation of endogenous opioids in the genesis of motion sickness were obtained in experiments on animals. Thus, the introduction of enkephalins into the IVth brain ventricle induced vomiting and changes in autonomic parameters (BP, HR, respiration) in alert cats. Use of microelectrode technology and the method of microiontophoresis of opioid peptides and morphine established high sensitivity to these substances in individual neurons of various morphofunctional structures of the brain stem (medial vestibular nucleus, respiratory and vasomotor bulbar centers and others), which are central links in the vestibuloautonomic reflexes. For example, it was demonstrated that enkephalins act as modulators of L-glutamatergic and cholinergic synaptic transmission in the medial vestibular nucleus. It was demonstrated that opioid peptides and morphine change the reactions of neurons in response to vestibular stimulation, in particular, the given reactions become less severe. Thus, opioids, along with acetylcholine and L-glutamate may participate in the central mechanism triggering motion sickness. In the majority of cases naloxon blocked the effects of opioid peptides and morphine, substantiating that opiate receptors are integral to the realization of these effects and suggesting that a possible central protective mechanism against motion sickness involves blocking these receptors. In addition, use of specific blockers of delta-opiate receptors ICI M 154.129 showed that the neural membranes of these structures contain mu- and delta-opiate receptors.

Thus, this research supports the hypothesis of the indirect participation of the endogenous opioid system in the genesis of vestibuloautonomic disturbances in motion sickness.

P842(18/88)* Davydov BI, Drobyshev VI, Ushakov IB, Fedorof VP.
Morphological analysis of the reactions of the brains of animals to short-term hyperoxia.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 56-62 ; 1988.

(19 references; 2 in English)

Neurophysiology, Brain Morphology

Rats, Dogs

Hyperoxia, Short-Term

Abstract: A total of 98 female Wistar rats and 20 dogs were studied in a semihermetic chamber into which pure normobaric oxygen was piped, at 8 l.min for rats and 22.3 l/m for dogs. Duration of exposure was 6, 18, 36, and 55 minutes for rats and 20 minutes for dogs. Subjects were sacrificed 0.1, 0.8, 1.7, 5, and 24 hours after treatment. Portions of sensorimotor and limbic cortices, the hippocampus, caudal nucleus, thalamus, hypothalamus, cerebellum, and medulla were isolated. Samples were fixed and poured into paraffin and celluloid. Neural and glial cells and their branches were stained. Total protein, amine groups, hydrosulfide groups, and RNA were measured. In order to determine enzyme activity, tissue blocks were formed, frozen in solid carbon dioxide in a cryochamber, and sections prepared. Activity of dehydrogenases, alkaline and acid phosphomonoesterase were observed. Parameters recorded for the sensorimotor cortices of both dogs and rats included: number of neural and glial cells in a unit area, percent of cells with reactive and destructive changes, percent of satellite glial cells and the neural-glial index. In the brain structures of dogs with inhomogeneous distribution of neurocytes, the percent of 500 neurocytes with reactive and destructive changes was noted. This computation was made for the head of the caudal nucleus, the anterior medial group of nuclei in the thalamus, field A₄ of the hippocampus, the fine-celled nuclei of the anterior hypothalamus, the nuclei of the vagus and glossopharyngeal nerves of the medulla, and among the Purkinje cells. Reactions of neurocytes were evaluated visually for the remaining brain structures. The large and small diameters of the neurocyte nuclei were measured karyometrically and the data used to compute their volume and the cells classified by size. Karyometric analysis was performed on neurocytes of the third and fourth layers of the sensorimotor cortex of rats and dogs. For ultrastructure analysis, portions of the brain were fixed, dehydrated, and ultrafine sections prepared and studied with an electron microscope. Concentrations of K and Na in blood plasma were also determined. Brain hydration was measured in various portions of the brain.

Results indicated that the brain shows a high degree of tolerance for hyperoxia. Optical microscopy indicated that the majority of nerve cells showed no changes. The greatest resistance were shown by the brain stem and cerebellum. The endbrain showed a number of different nonspecific changes which could be divided into: reactive, destructive, and compensatory-adaptive. Reactive changes were highly diverse and included changes in shape and size, vacuolization of cytoplasm, and changes in tinctural properties. However, neurocytes retained their major properties, the nucleus maintained its integrity, and changes appeared reversible. Reactive changes were statistically significant in the sensorimotor cortex of rats, and the hippocampus and caudal nucleus of dogs 5 hours after hyperoxygenation. Destructive changes appeared irreversible. Most often

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these involved pyknomorphic cells, small, elongated and spindle-shaped. The cytoplasm of such cells was homogenized and in many cases the contours of the nuclei were not detectable. Some cells lacked nuclei and nucleoli. Such cells were found at all observation periods and were significant in the sensorimotor cortex of rats after 1.7 and 5 hours and in the hippocampus of dogs after 5 hours. Compensatory changes noted included increased concentration of protein and nucleic acids and increased staining intensity for free amino acids and hydrosulfide groups.

Results of electron microscopy confirmed the resistance of the brain to destruction from hyperoxygenation. However, a number of ultrastructural changes were observed in neurocytes. These were most polymorphic in the sensorimotor and limbic cortices and hippocampus. The most common changes were cells with increased osmophilic nuclei and cytoplasm. These cells contained many small vacuoles. Cytoplasm showed abnormal formation of membrane complexes. Late observations revealed increased lysosomes and increased acid phosphomonoesterase activity. All brain areas studied showed some pyknomorphic cells. Changes in nuclei included dispersed chromatin, chromatin condensed on the karyolemma, hypertrophied nucleoles, eccentrically located, with loss of ribonucleoproteins. In the sensorimotor cortex of rats the nuclei were decreased in size. Karyometry showed diminished nucleus size in sensorimotor neurocytes in dogs, while neurocyte nuclei in the hippocampus were enlarged. Activity of succinate dehydrogenase was unchanged, as was lactate dehydrogenase activity. No significant changes occurred in neurofilaments, synapses, or other specialized elements. Elements of the hematoencephalic barrier were also not affected significantly.

When duration of hyperoxia was low, no changes were found in brain hydration of rats. However, some effects were noted as duration of hyperoxia increased, mainly hyperhydration in the cerebral cortex.

Table 1: Changes in the sensorimotor cortex of rats after 55 minutes of hyperoxia

Table 2: Changes in brain neurocytes of dogs 5 hours after hyperoxia

Table 3: Changes in hydration profile of the brain after exposure to pure normobaric oxygen varying in duration

Figure 1: Sensorimotor cortex of rats 1.7 hours after hyperoxia

Figure 2: Sensorimotor cortex of dogs 5 hours after hyperoxia

Figure 3: Size distribution of neurocyte nuclei in the sensorimotor cortex and hippocampus of dogs

P844(18/88)* Vasil'yev AA, DiyeV AV, Grigorenko AB.

An automated vestibulometric device.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 66-67 ; 1988.

(5 references; none in English)

Neurophysiology, Vestibular System

Equipment and Instrumentation, Vestibulometric Device

Acceleration

Abstract: This paper describes a vestibulometric device capable of producing graded levels of acceleration, recording their biological effects, and processing the data obtained on-line. The data processing capacity in particular represents an improvement over other available Soviet devices. The present instrument uses a microcomputer, a set of programs for controlling a motor, and apparatus for recording and measuring electrical physiological data, a vestibulometric chair with a cable, a control block with a thyristor power source for the motor, a block for the recording and processing of the electric biodata, and a block for controlling the angle of the chair. The computer provides an interactive interface through which the experimenter can set the rotation schedule and experimental protocol, adjust recording of biological signals, and create a file to store data.

P847(18/88)* Yasnetsov VV, Drozd YuV, Shashkov VS, Bragin YeO, Popkova YeV, Vabishchevich AV.

Protective effects of certain peptides with respect to motion sickness in animals.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 72-73 ; 1988.

(1 reference; none in English)

Neurophysiology, Motion Sickness

Cats

Protective Effects, Peptides

Abstract: Seven male cats had canulas implanted in the IV ventricle of the brain. Substance R, gamma-endorphin, des-Tyr-gamma-endorphin, and also ACTH in doses of 10-100 ug dissolved in sterile saline solution were introduced through this canula in a volume of 50 ul over 3-5 minutes before vestibular stimulation. Motion sickness was induced using an undescribed method and severity was rated on a rating scale. All the preparations used, with the exception of ACTH, had protective effects against motion sickness, especially pronounced for substance R. ACTH, conversely, enhanced motion sickness symptoms. In an additional experiment, rats were exposed to motion sickness induction and the concentration of lev-enkephalin in their brains was measured. The treatment led to a significant decrease of lev-enkephalin in the cerebellum, brain stem, and adrenal glands.

NUTRITION

(See also: Aviation Medicine P813; Metabolism P829, P838)

PAPERS:

P848(18/88)* D'yakonov MM, Kudrin ID, Stolyarova NA.

Work capacity and bioenergetics in older individuals on reduced flight rations.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 73-74; 1988.

(14 references; 2 in English)

Human Performance, Work Capacity, Bioenergetics

Humans, Older

Nutrition, Flight Rations

Abstract: Over the course of 10 days, 9 subjects with mean age of 56, performed their usual jobs while eating a daily diet consisting of 2 flight rations per day, totalling 1128 calories and containing 34.1 g protein, 37.5 g fat, and 155.9 g carbohydrates. Subjects' energy expenditure was studied using the gas exchange method. Work capacity was measured with graded physical exercise on a bicycle ergometer. Functional state and mental work capacity were studied using a variety of tests (e.g., visual motor reaction time, memory search). Nutritional status was evaluated on the basis of body weight, fat component, dynamics of carbohydrate, lipid, and nitrogen metabolism, water consumption, and diuresis.

Throughout the experiment subjects did not complain of feeling ill or hungry. The amount of work they performed would be associated in USSR nutritional standards with a caloric intake 1100-1200 calories over what was provided. After 10 days, subjects had lost an average of 2.1 kg, including 1.2 kg fat. Weight loss could not be attributed to fluid loss. On the basis of values for daily excretion of nitrogen, loss of fat and concentration of lipids in the blood, it was concluded that 57% of the lost weight was fat, 33% carbohydrates and 10% protein. No changes in physical work capacity (as measured by oxygen consumption during exercise) were noted. Basal metabolism decreased. Fasting blood sugar fluctuated throughout the period, with some moderate hypoglycemia noted during the middle of the period, followed by recovery to above baseline level. This suggests that during this period, processes of gluconeogenesis were activated using endogenous reserves of nutrients, resulting in increased blood sugar and stable work capacity. Total blood lipids, high density lipids, and triglycerides decreased while nonesterified fatty acids increased. No evidence of acidosis was detected and no changes in functional state or mental work capacity were noted. Use of flight rations is recommended for weight loss programs for older individuals.

Table: Changes in major metabolites during the experimental period

OPERATIONAL MEDICINE

(See also: Aviation Medicine P832, BR13; Space Biology and Medicine M125; Special Feature P856)

PAPERS:

P811(18/88) Vabishchevich AV.

The potential use of long-acting peridural anaesthesia on long-term space flights.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 29-31.

Operational Medicine, Peridural Anaesthesia, Long-Acting
Humans, Cosmonauts, Theoretical Article
Space Flight

Abstract: The increased duration of space flights, and the increased complexity of the special operations which are performed in orbit enhance the risk of cosmonauts developing a variety of diseases, traumatic injuries, burns, fractures, etc. The inclusion of a physician in the flight crew makes it possible to use delicate surgical and anaesthesiological procedures in treating disease. In the author's opinion one of the most promising methods for providing specialized anaesthesiological-resuscitatorial aid during space flight is long-acting peridural anaesthesia (LPA). LPA is being used successfully in clinical practice in the treatment of a wide range of maladies.

The advantage of LPA is that it is relatively simple to use, can be utilized in weightlessness, requires relatively simple and portable equipment, and has minimal effects on the cardiovascular and respiratory systems. Research results have shown that use of LPA under conditions of hypokinesia with head-down tilt with an angle of -8° and during a recovery period produces an anaesthetic effect sufficient for major operations on organs of the abdominal cavity and lower extremities. Changes in the vital organs and systems were minimal and did not affect the subjects' state. Clinically, LPA was used by the author in urological and obstetric practice, and in older subjects undergoing vascular reconstruction, etc. It was demonstrated that LPA is the method of choice and is preferable for older subjects with altered reactivity and accompanying cardiovascular and respiratory problems.

To simplify the process of puncture and catheterization of the peridural space, the author has proposed a technique for identifying the peridural space by recording changes in electrical resistance of tissues. A pilot model instrument made it possible to perform peridural puncture with high accuracy and avoid technological errors and complications.

Small doses of narcotic anaesthetics (morphine, promedol) are promising for use in support of LPA. When these and similar drugs are injected into the peridural space, anaesthesia lasts for many hours, and the small doses

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required preclude pathological effects on vital systems. Use of electrostimulation of the roots of the spinal nerves with electrodes inserted in the peridural space is of considerable interest as well. This method makes it possible to completely eliminate the use of drugs for LPA and to select amounts of anaesthesia on an individual basis.

P816(18/88) Chadov VI, Chernyakov IN, Iseyev LR, Polyakov VN, Prodin VI, Shishov AA.

Study of the characteristics of decompression gas formation under conditions simulating weightlessness.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 154-155.

Operational Medicine, Decompression

Humans

Weightlessness Simulation, Head-Down Tilt, Oxygen Breathing

Abstract: Cosmonauts may be required to perform an EVA during the initial (acute) period of adaptation to weightlessness, i.e., during the first few days of the flight. In addition to the subjective experience of discomfort, this period is marked by observable hemodynamic changes, related to fluid shifts in the body, which may significantly impair an individual's well-being, state, or work capacity. Since the cosmonaut performing an EVA wears a suit in which absolute pressure is below that of the spacecraft cabin, it is possible that high-altitude decompression sickness will occur and that the cosmonaut, because of his weakened state, will have little or no resistance to it. There is no published information about the characteristics of the development and manifestations of high-altitude decompression sickness under such conditions; however, there is data suggesting the possibility that elimination of inert gas will be faster under conditions simulating weightlessness (immersion, horizontal hypokinesia) if oxygen is breathed.

The authors performed preliminary research to identify the characteristics of the onset and symptoms of high-altitude decompression sickness in humans undergoing head-down tilt. A total of 47 trials were conducted with 22 subjects under laboratory conditions in a barochamber with a rarefied atmosphere. The same individuals were tested under control (sitting position) and experimental (-15° head-down tilt) conditions. Head-down tilt of -15° simulated the effect of cephalad fluid shifts, such as those that occur in the acute period of adaptation to weightlessness. Ascent in the barochamber occurred at a rate of 25 m/sec, and duration of exposure to the altitude was limited to 3 hours.

In addition to the usual monitoring techniques used in such conditions, the authors introduced the use of an ultrasound Doppler device for locating decompression gas bubbles in the pulmonary artery. Evaluation of gas formation rate used a modified Spenser scale.

The first experiment (12 subjects, 22 trials) was conducted with an absolute pressure of 220 mm Hg and with subjects in a state of relative rest. Preliminary decompression was absent, but supplementary oxygen was given starting when pressure was 405 mm Hg ("altitude" of 5 km). In the second experiment absolute pressure was 180 mm Hg and light physical exercise (extension and flexion of the arms and legs) was performed. Partial

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preliminary decompression was accomplished by having subjects breath pure oxygen under sea level conditions for a period of up to 25 minutes.

In the first experiment, there were 2 cases of high-altitude decompression during ascent in an upright position, while there were none in head-down tilt position. In the second experiment, with more severe conditions, decompression sickness predictably occurred more frequently, with 6 cases in sitting position and 5 cases in head-down tilt of -15° .

Decompression aeroembolisms, located using ultrasound, occurred in the blood of the pulmonary artery before symptoms of decompression sickness appeared and continued after symptoms abated. There was a direct correlation between an individual's susceptibility to high-altitude decompression sickness in upright and head-down tilt position and tendency to form gas bubbles in the blood. Individuals susceptible to decompression gas formation developed decompression sickness more frequently and in a more severe form, than did resistant individuals. It was also demonstrated that in head-down tilt position, decompression sickness occurs later and in a less severe form, and abates more readily when pressure increases, than that occurring in upright position. It should also be noted that in a head-down tilt position barofunction is more adversely affected by descent from a height, due to blood pooling in the head.

On the basis of these studies, which are still too few in number, one can hypothesize that high-altitude decompression sickness during the acute period of adaptation to weightlessness will be no more frequent or severe than occurs under ordinary circumstances.

PERCEPTION: See Aviation Medicine BR13; Gravitational Biology M132;
Personnel Selection M127; Psychology M130)

PERSONNEL SELECTION

(See also: Aviation Medicine BR13; Hematology P845, Psychology M131)

MONOGRAPH:

M127(18/88) Makharenko NV, Pukhov BA, Kol'chenko NV, Maydikov YuL, Kiyenko VM, Voronovskaya VI.

Osnovy professional'nogo psikhofiziologicheskogo otbora [**Principles of psychophysiological occupational selection**].

Kiev: Naukova Dumka; 1987.

[244 pages; 37 tables; 44 figures; 244 references; 10 in English]

Affiliation: A.A. Bogomolets Institute of Physiology; Ukrainian Academy of Sciences.

KEY WORDS: Personnel Selection, Psychology, Human Performance, Neurophysiology, Group Dynamics, Perception

Annotation: This monograph presents the theoretical and methodological principles of psychophysiological occupational selection. It describes methods of research, the major properties of higher nervous activity, neurodynamic processes, psychodynamic functions and personality traits, as well as methodological approaches to the formation of small working groups. Using the results of studies of drivers in the trucking industry, operators of modern thermal power stations, air traffic controllers, telephone and radiotelegraph operators, the authors demonstrate the significance of the major properties of the nervous system and of psychophysiological and personality traits to job performance. This book is intended for specialists in psychophysiology, physiology of human higher nervous activity, industrial and sports physiology and ergonomics.

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PSYCHOLOGY

(See also: Biological Rhythms P819; Hematology P827; Neurophysiology P814; Personnel Selection M127; Special Feature P856)

PAPERS:

P818(18/88) Zhdanov OI, Shpatenko YuA.

Intentional self-regulation as one of the factors in on-the-job adaptation to extreme performance conditions.

In: Gazenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 166-167.

Human Performance, Adaptation

Humans

Psychology, Self-Regulation, Stress, Extreme Conditions

Abstract: In many ways, contemporary life styles do not accord with traditional ways of living. Scientific and technological progress has significantly expanded the range of human activity. The Pacific Ocean and space, as well as inaccessible regions with severe climatic and geographic conditions are being assimilated rapidly and extensively. Humans are actively colonizing unfamiliar environments. Successful adaptation under these conditions is an important factor from the standpoint of productive work and the development and realization of the individual's potential. As a rule, job performance under extreme conditions is marked by nervous tension. Such stress is caused by a number of factors, such as a high level of responsibility for the result; some degree of threat to human life; rigid work schedules; likelihood of emergencies; other elements of uncertainty, novelty, and insecurity; and finally, adverse psychological, physiological, and hygienic living conditions, and work and rest schedules. A negative phenomenon, nervous stress fosters the development of a rather broad spectrum of functional states which result in decreased performance efficiency and reliability of the worker. Active combat of nervous stress is one way to ensure successful human adaptation to extreme living conditions. The adaptation process can be gauged objectively through individual performance style. Individual performance style is a term which refers to a system of psychological measures unique to an individual, to which he consciously or intuitively resorts in order to achieve the best possible balance between his personality and performance conditions. Goal-directed self-regulation of behavior, its emotional concomitants, and psychological activity as a whole decrease the uncontrolled element in the adaptation process, bringing it under conscious control. Self-regulation in this sense refers to a person's active efforts not only to assimilate to the environment, but also to transform it in accordance with his needs. An active relationship to the world, search for meaning and vital values, and the struggle to reach a goal are essential prerequisites for psychological health. The goal-directed, active personality is relatively free from dependence on the inessential characteristics of his environment. This relative freedom engenders a particular style of interaction with the

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environment -- a strategic type of regulation and behavior. It entails a goal-directed review of criteria relevant to evaluation of events, and eliminates many inessential problems, freeing the individual from a continual avalanche of trivia. No less important is the development of feelings of optimism, the capacity to seek out the positive side of any negative situation. This leads to the development of an integrated personality, focussed on overcoming difficulties without discouragement and anxiety. A person who is able to find the positive is capable of retaining his perspective, solving the complex problems set by life, and realistically assessing any situation and finding a solution. Successful adaptation to special conditions facilitates development of a positive emotional state. Ability to be happy is very productive. It is useful to one's self and others, while the habit of seeing only the negative tends to cause one's view of the world to be based mainly on negative factors, with a disastrous influence on a person's actions, relations with others, and psychological health. Finally, the possession of skills of self-mastery is an essential condition for maintaining efficient performance and professional longevity. These skills include intentional regulation of respiration, muscle and vascular tonus, cardiac function, and other systems. The significance of such regulation lies in goal-directed reproduction of the most situation-appropriate sensations which comprise the somatic component of the state. Active attitudes of the job performer are also important because the most accurate and effective formulae for self-mastery are created by the individual himself on the basis of analysis of his own spontaneous, positive sensations induced by a variety of situations.

This paper presents the basic principles of intentional self-regulation as a means of actively combatting the effects of extreme job performance conditions. It touches on acquisition of behavioral habits, social skills, the development of a positive emotional tone, and sensory reproduction of the necessary subjective sensations. An active attitude on the part of the job performer, his goal-directedness, and drive for self-actualization are essential conditions of conscious self-regulation.

MONOGRAPHS:

M130(18/88) Furdyy FI, Kaydarliu SKh, Shrirby YeI, Nadvodnyuk AI, Mamalyga LM.

Mekhanizmy razvitiya stressa: Stress, adaptsiya i funktsional'nyye narusheniya [**Mechanisms underlying the development of stress: Stress, Adaptation and Functional Disorders.**]

KEY WORDS: Psychology, Stress, Adaptation, Neurophysiology, Immunology, Endocrinology, Space Flight, Biological Rhythms, Pharmacological Countermeasures, Developmental Biology, Gastrointestinal System,

Annotation: This collection provides information concerning the current status of the problem of stress and cites new experimental data on mechanisms underlying its development. Emphasis is placed on explicating the roles of the neural, endocrine, immune, and other systems in the development of the stress reaction. The characteristics of human stress arising during space flight are described. Ontogenetic data which facilitate a deeper understanding of the mechanisms underlying the development of the stress reaction are given. The rhythmic aspects of stress and adaptive reactions are discussed and a taxonomy presented. Means of controlling stress using pharmacological agents are described. This book is intended for biologists and medical personnel dealing with stress and adaptation and also for physiologists and pharmacologists.

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PSYCHOLOGY

M131(18/88) Platonov KK, Gol'dshtein BM.

Osnovy aviatsionnoy psikhologii [**Principles of aviation psychology.**]

Moscow: Transport; 1987.

[222 pages; 9 tables; 19 figures; 32 references; none in English]

KEY WORDS: Psychology, Aviation Psychology, Stress, Pilots, Human Performance, Small Groups, Training, Perception, Personnel Selection, Man-Machine Systems

Annotation: This book defines and discusses the basic concepts of psychology. It considers the psychological aspects of flight and preparation for flight, and the effects of space flight factors on psychological performance of pilots. Emphasis is placed on the psychological training of student pilots, and the psychological compatibility of flight crews. This book is intended for students at specialized secondary educational institutions for civil aviation and may also be used by flight and control personnel in civil aviation, and physicians.

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RADIOBIOLOGY

(See also: Adaptation P824; Immunology P843)

PAPERS:

P812(18/88) Il'in VA, Neumyvakin IP, Kondrat'yev II.

The potential use of ultraviolet irradiation of the blood in the practice of space medicine.

In: Gizenko OG (editor).

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina: Tezisy dokladov VIII Vsesoyuznoy Konferentsii, Kaluga, 25-27 June 1986 [Space Biology and Aerospace Medicine: Abstracts of papers delivered at the Eighth All-Union Conference, Kaluga, 25-27 June 1986].

Moscow: Nauka; 1986.

See: Abstract M117 (Space Biology and Medicine) Digest Issue 14.

Pages: 64-65.

Operational Medicine, Space Flight, Immunology, NonSpecific Resistance
Humans, Cosmonauts, Theoretical Article
Radiobiology, Ultraviolet Radiation, Hematology, Blood

Abstract: To maintain the health and work capacity of cosmonauts during long-term flights, it is extremely important to find means and methods of increasing the nonspecific resistance of the human body to the effects of space flight factors, and also of treating diseases. One of the most promising methods therein is the use of autoblood (their own blood) irradiated with ultraviolet rays. The use of this method in treating septic states, allergic disorders, chronic nonspecific illnesses, and post-traumatic peritonitis has shown it to be highly effective, and capable of shortening preoperative preparation and preventing various complications. Acceleration of recovery processes and faster restoration of work capacity in the convalescent period also have been demonstrated. These results are caused by the nonspecific effects of ultraviolet irradiation leading to improvement of hemorheology, increased arteriovenous oxygen differentials, and osmotic resistance of erythrocytes. At the same time, concentrations of cholesterol, blood sugar, bilirubin, and potassium and sodium ions decrease, and activity of proteolytic and lipolytic enzymes increases.

Thus, the clear nonspecific effects of irradiating blood with ultraviolet justify recommending this method for use alone or in combination with other means, for use in the practice of space medicine to increase nonspecific resistance of cosmonauts, accelerate adaptation to extreme factors, readaptation to Earth's gravity, and treatment of a variety of functional disorders and diseases regardless of their pathogenesis.

P853(18/88)* Gerasimenko VN, Zukhbaya TM.

Properties of radiation damage and reparation in bone marrow of mice irradiated with 4 GeV/nucleon helium ions and 9GeV protons.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 85-87; 1988.

(9 references; 1 in English)

Musculoskeletal System, Bone Marrow

Mice

Radiobiology, Helium Ions, Protons

Abstract: In this study, mice of the F₁ line were irradiated by a synchrotron with protons of energy 9 GeV and helium ions with energy 4 GeV/nucleon in a dose of 4 Gy. Dose rates were 0.5 or 2 Gy/second, respectively. As a standard, radiation gamma irradiation from ¹³⁷Cs at a dose rate of 0.0245 Gy/second was used. Six animals [in each group] were sacrificed on days 1, 3, 5, 7, 10, 15, and 30 post-irradiation. Absolute number of cells in the femur bone were counted. Extent of damage to marrow was assessed using the equation $\lg \frac{N}{N_0}$, where N and N₀ are the number of

nucleated cells in the femurs of irradiated and control animals. Rate of reparation processes in the hemopoietic tissue was evaluated by observing changes over time in this parameter, and the time period required for 50% recovery was noted.

Results are plotted in Figure 1. All curves show similar phase structures. Maximum decrease in the number of karyocytes (days 1-3) was more pronounced after proton and ion irradiation than after gamma irradiation. Lack of difference between the two types of charged particles may be explained by their virtually identical linear energy fluxes. Dose rate of helium ions did not affect radiation damage. Rate of recovery of hemopoietic tissue after irradiation by helium ions and gamma radiation did not differ, but both were significantly faster than rate of recovery after proton irradiation. Recovery curves conformed to the principle of exponential growth with two components — fast and slow. Fifty percent recovery time for the fast period was 2.5 days for gamma irradiation and helium ions, but was 4.5 days for protons. The fact that recovery of hemopoietic populations was faster for helium ions than for protons is interesting in light of the greater damage done to individual cells by helium ions. The authors hypothesize that the faster rate of population recovery for helium-ion damaged cells may be a compensation for lower reparative capacity.

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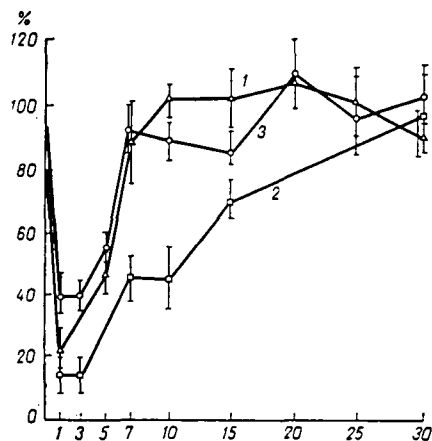


Figure: Changes over time in karyocytes in the femur bones of mice after irradiation with (1) helium ions, (2) protons, and (3) gamma rays ^{137}Cs in a dose of 4 Gy. Abscissa - days, ordinate: number of karyocytes (in % of control)

REPRODUCTIVE BIOLOGY: See Adaptation P822; Body Fluid P836; Genetics P850

SPACE BIOLOGY AND MEDICINE

MONOGRAPH:

M125(18/88) Verigo VV.

Systemnyye Metody v Kosmicheskoy Biologii i Meditsine. Problemy Kosmicheskoy Biologii. Tom 55. [**Systems Methods in Space Biology and Medicine. Problems in Space Biology. Volume 55.**]

Moscow: Nauka; 1987.

[216 pages; 12 tables; 75 figures; 17 pages of references]

KEY WORDS: Space Biology and Medicine, Simulation Modeling, Systems Theory, Mathematical Modeling, Homeostasis, Operational Medicine, Cardiovascular and Respiratory Systems, Body Fluids, Cytology, Immunology, Hematology, Life Support Systems, Metabolism, Calcium, Exobiology, Planetary Quarantine, Microbiology

Annotation: This monograph is devoted to the use of methods from systems theory in space biology and medicine. It examines their use in the prediction of future development in these scientific areas, the use of simulation modeling in the evaluation of the state of various physiological systems, quantitative research on design of artificial microecosystems and a number of other multidisciplinary issues. This book is intended for specialists in space biology and medicine and also for researchers in biophysics and mathematical biology.

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SPACE INDUSTRIALIZATION

MONOGRAPH:

M128(18/88) Grishin SD, Leskov LV.

Industrializatsiya kosmosa: Problemy i perspektivy [**Industrialization of space: Problems and prospects.**]

Moscow: Nauka; 1987

[353 pages; 26 tables; 111 figures; 356 references]

KEY WORDS: Space Industrialization, Materials Processing, Exobiology, Weightlessness

Annotation: This book considers the current status of the problem of industrial exploitation of space. It describes achievements in the physics of weightlessness as the scientific basis for methods of space technology and space construction and analyzes the status of developments in power and propulsion units for spacecraft used for space industrialization purposes. On the basis of this analysis, the authors perform a critical review of design research in the major areas of space industrialization. Using systems methods they create a super long range scenario of the successive stages in space industrialization. This book is intended for engineers interested in the problems and prospects of exploitation of space, and also for instructors, students, and graduate students working in relevant areas.

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**SPECIAL FEATURE: LETTER TO THE EDITOR ON THE SIGNIFICANCE OF THE
GRAVITATIONAL FACTOR IN THE FINAL STAGE OF SPACE FLIGHT**

P856(18/88)* Bryanov II, Yerebin AV, Stepanov VI.

On the significance of the gravitational factor in the final stage of space flight.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

22(2): 93-95 ; 1988.

(17 references; none in English)

KEY WORDS: Gravitational Biology, Space Flight, Reentry, Operational Medicine, Adaptation, Neurophysiology, Motion Sickness, Orthostatic Intolerance, Body Fluids, Fluid Redistribution, Cardiovascular and Respiratory Systems, Endocrinology, Musculoskeletal System, Provocative Tests, Deceleration, Impact, Psychology, Stress

Translation: Many years of experience with providing medical support to manned space flight and the results of numerous and varied medical and biological investigations in space and in ground-based simulations have demonstrated that space flight factors induce a series of functional and structural changes in the body, which are mainly adaptive in nature. The initial period of exposure to weightlessness, where humans encounter an unfamiliar, alien environment, is of particular interest and importance. This period is the setting for: rapid and radical restructuring of sensory systems; the appearance of a unique syndrome, similar to motion sickness; fluid redistribution in the cranial direction, with the associated hemodynamic and endocrine shifts; and accommodation reactions of the neuromuscular system. This initial period of adaptation sometimes lasts for as long as 3-7 days. Severity of its symptom is extremely variable and subject to individual differences.

Further adaptation to space flight conditions and factors usually proceeds without striking manifestations. Results of medical modeling and medical research in- and postflight have revealed no pathological changes in cosmonauts even after 8-month flights (although crews did use certain prophylactic countermeasures). At the same time, adaptation to flight conditions and life in weightlessness is accompanied by decreased tolerance of gravity, particularly orthostatic intolerance, and leads to atrophic changes in the musculoskeletal system, changes in visceral organs, etc. The organization and coordination in the functioning of sensory systems, particularly gravity-dependent systems, which developed on Earth, must undergo restructuring: a new hierarchy must govern their interactions. In other words, the body undergoes a transition to a new level of functioning, different from that characteristic of Earth.

Cosmonauts' general condition, the state of their functional physiological reserves are evaluated on the basis of results of medical examinations, including those using provocative (loading) tests. Usually these results are compared with data from analogous examinations conducted during the preflight period. Can the legitimacy (validity) of such comparisons be questioned? Given the fact, that in weightlessness, the nature and magnitude of a provocative stimulus are inevitably altered, is it really a good sign when, after several months of flight, reactions to this stimulus test do not differ from those on Earth? Which changes should be considered acceptable

THE GRAVITATIONAL FACTOR IN THE FINAL STAGE OF SPACE FLIGHT

and which undesirable? Not only does the correct evaluation of the current condition of a cosmonaut depend on the answer to these questions, but so do the appropriateness and adequacy of prophylactic countermeasures, as well as prognosis of physiological responses to the final stage of flight and condition on reentry, and development of an appropriate strategy for [medical] management of cosmonauts during the readaptation period. In other words, the answers to these questions will, to a significant extent, determine the general strategy for medical support of space flights.

The appropriateness and efficacy of countermeasures to prevent adverse effects of space flight are evaluated on the basis of the extent to which results of postflight examinations differ from preflight data. These results also serve as the basis for developing measures to facilitate readaptation. In this enterprise, it is accepted as a given that all or almost all changes observed in postflight examinations were caused by the preceding long-term exposure to weightlessness. This same presupposition also serves as a basis for planning ground-based simulation experiments to study various aspects of space biology and physiology.

It is our opinion that space scientists have not been justified in minimizing or underestimating the significance and role of a number of factors affecting the body during the final stage of space flight and after reentry, particularly the gravity factor. Indeed, during this stage of deorbit and deceleration in the upper layers of the atmosphere (before opening of the main parachutes), the cosmonauts are exposed for many minutes to forces up to 4-G, which they themselves subjectively rate as being 1-2-G higher. During the landing stage, as the engines provide a soft landing and then at the moment of contact with Earth, cosmonauts are exposed to short-lived but quite pronounced impact forces. And after this the cosmonauts fall into the "heavy embraces of the Earth." During the first few hours after reentry, cosmonauts feel the Earth's gravity as a constantly present G-load equal to 1.5-2-g, or at times even greater. Only on day 2, or less frequently day 3, does this sensation of increased body weight disappear.

In addition, toward the end of a flight, cosmonauts have been observed to show signs of asthenization, and during the final stage experience substantial emotional stress.

Thus, postflight medical observation of cosmonauts actually begins during reentry G-load, which is marked by pronounced emotional stress, and constantly increasing everpresent "hypergravity." As is well known, each of these factors can give rise to pronounced physiological effects. Thus, one may hypothesize that postflight examinations reveal the reactions of an organism adapted to weightlessness in a state of emotional stress reaction, to the effects of acceleration (G-load) and terrestrial gravity. It should be emphasized that gravity itself in this situation is the same kind of stressogenic factor as weightlessness was at the beginning of the flight and requires prompt readaptation of those physiological systems and structures which had become adapted to weightlessness.

The reactions of the neuromuscular (musculoskeletal) and sensory systems are especially striking from this point of view. Research has shown that return to Earth's gravity postflight is accompanied by manifestations

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phenomenologically similar to those observed during the early period of adaptation to weightlessness. It has also been demonstrated that the severity of these phenomena increases with increase in flight duration (i.e., with a longer period of biological adaptation to weightlessness).

Of course, one cannot exclude the direct physiological effects of weightlessness and living conditions on the spacecraft. There is no doubt that these factors give rise to hematological and immunological shifts, changes in fluid electrolyte metabolism, muscle atrophy, disruption of coordination, physical deconditioning (including cardiovascular deconditioning), and others. However, the severity of certain changes is enhanced by the effects of the set of factors operating during the final stage of the flight and postflight "hypergravity," as discussed above. For this reason, it is essential to clearly determine and "partial out" the effects of these factors.

One of the ways to do this, obviously, must involve development of apparatus for obtaining correct and complete data on the functional state of the major physiological systems during flight, and also the extent of correlation between these data and the results of pre- and postflight examinations. It would be still more effective to conduct research on board spacecraft with participation of a highly-trained physician. The information gained from space flights of Soviet and American physicans convincingly demonstrates the fruitfulness of such an approach.

Another approach, which would supplement rather than replace the first, would involve improvement of methods for simulating space flight conditions in ground-based experiments. Previous experiments of this type have simulated the hypokinetic and hemodynamic effects of weightlessness more or less correctly. Obviously it is essential to develop methods for reproducing and simulating the factors and conditions of the final stage of flight, as mentioned above. In particular, after long-term immersion or hypokinesia with head-down tilt, it would be desirable to reproduce stress-producing work conditions (possibly with sleep deprivation), the G-load effects of reentry and impact and the subsequent hours of activity (to include even short breaks allotted to eating and other natural functions and conduct of medical tests similar to those given in postflight exams), and to simulate Earth's "hypergravity" and then to evaluate the combined effects of these factors on a body adapted to weightlessness. Undoubtedly, it would also be useful to reproduce the psychological aspects of flight and the stress of the final stage.

SPECIAL FEATURE: COSMONAUT SELECTION

Trofimov V. Invitation to space. From Izvestiya, April 1, 1988.

KEY WORDS: Cosmonaut Selection

The enormous successes of Soviet cosmonautics have confirmed the high efficiency of our methods for selecting and training cosmonauts. Currently, it has been decided to improve these processes in order to enlist the participation of highly qualified specialists in a variety of areas in the study and conquest of near-Earth space, and the utilization of the achievements of space technology in the economy. Here is the information obtained by our correspondent:

"During the 27 years since man was first launched into space, we have conducted an enormous amount of biomedical experiments and research to study human reactions to the long-term and short-term effects of space flight factors. All this has made it possible to expand today's contingent of cosmonauts and radically simplify the entire procedure for cosmonaut selection. In essence, we are standing on the threshold of a whole new stage in space flight, involving the participation of an ever-increasing number of space aficionados.

"Plans call for opening a special bureau to consider applications from individuals wishing to devote themselves to the study and conquest of space. The list of documents candidates must supply will include an application to become a cosmonaut, an autobiography, transcript from a higher educational establishment or military college, an employer's or military service recommendation, four 6 X 9 photographs and a health certificate signed by a physician. The age range which has been established is 22-40 for men and 22 to 30 for women.

"As is well known, on 17 March the Soviet Vostok launch vehicle placed the Indian satellite IRS-1A into orbit. An analogous commercial arrangement will be developed to accept potential cosmonauts from all states with which the USSR has diplomatic relations."

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16. Abstract This is the eighteenth issue of NASA's USSR Space Life Sciences Digest. It contains abstracts of 50 papers published in Russian language periodicals or presented at conferences and of 8 new Soviet monographs. Selected abstracts are illustrated with figures and tables from the original. A book review of a recent Aviation Medicine Handbook is also included. The abstracts in this issue have been identified as relevant to 37 areas of space biology and medicine. These areas are: adaptation, aviation medicine, biological rhythms, biospherics, body fluids, cardiovascular and respiratory systems, cytology, developmental biology, endocrinology, enzymology, equipment and instrumentation, exobiology, gastrointestinal system, genetics, gravitational biology, group dynamics, habitability and environmental effects, hematology, human performance, immunology, life support systems, man-machine systems, mathematical modeling, metabolism, microbiology, musculoskeletal system, neurophysiology, nutrition, operational medicine, perception, personnel selection, psychology, radiobiology, reproductive biology, space biology and medicine, and space industrialization.					
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